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JOURNAL OF PALEONTOLOGY

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The American Association of Petroleum Geologists

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JOURNAL of PALEONTOLOGY

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FOSSIL HOLOTHUROIDEA*

CAREY CRONEIS AND JOHN MC CORMACK
University of Chicago

ABSTRACT

The calcareous bodies of the main types of modern holothurians are illustrated, and described from the paleontologic point of view. All of the known references to fossil holothurians are examined and summarized, and the figures presented in rare publications are reproduced. Three new genera, *Protocaudina*, *Paleochiridota*, and *Etheridgella*, are defined and ten species (seven new) of North American fossil holothurians are described and figured. The relationships of recent and fossil holothurians are discussed, and a tentative outline of the geologic development of the class is presented. The possible value of the calcareous plates of these animals as micropaleontologic objects is discussed, and the difficulties involved in their use as index fossils are outlined. A complete bibliography is appended.

INTRODUCTION

"Few classes of animals have a less satisfactory geological record than the holothurians, and every fragment that can be gathered is therefore of unusual interest and importance." So wrote Dr. H. L. Clark (24) † twenty years ago, but the statement is just as accurate now as it was then. Some idea of the *apparent* paucity of holothurian remains in the rocks of North America may be gained from the fact that only ten references on the subject are known, and seven of these concern a single discovery. This is in marked contrast to the annual appearance of a score or more of papers dealing with modern holothurians.

During the course of micropaleontological examination of a suite of Illinois Chester samples, there was discovered a series of calcareous deposits of holothurians. In attempting to classify these bodies, a complete canvass of the literature was made which has yielded surprizing results. Previous workers have assumed that essentially no literature on fossil holothurians existed, and have contented themselves with at most three or four references. As a matter of fact, although references are not common, we have found fifty-five citations of fossil holothurians. Most of these are in foreign publications, many, indeed, are in very obscure journals, and in a majority of cases the reference concerns less than a paragraph. Because of the rarity of many of the publications involved, and because many of them are un-

* Published by permission of M. M. Leighton, Chief, Illinois Geological Survey. Given (in part) before Illinois Academy of Science, May 8, 1931. Presented before Paleontological Society, Dec. 29, 1931.

† The numbers refer to the bibliography at the end of this paper.

available except in a very few American libraries, we have appended the first essentially complete bibliography of fossil holothurians. Furthermore, in order to facilitate the work of those outside of great library centers, we have figured most of the holothurian remains illustrated by foreign workers. Finally, we have selected from the voluminous literature about a score of the modern holothurian references which should be of greatest interest to the paleontologist; and we have illustrated the types of modern holothurian deposits for use as a basis of comparison in micropaleontological investigations.

ACKNOWLEDGMENTS

The writers are pleased to acknowledge their indebtedness to Dr. M. M. Leighton, Chief of the Illinois Geological Survey, through whose kindness they were able to study a complete suite of Chester samples from Illinois and to present this paper for publication. They are also indebted to J. E. Lamar and L. E. Workman of the Illinois Survey for information concerning the samples which were collected by them or under their supervision. Their best thanks are also due Mrs. Helen Jeanne Plummer for her kindness in supplying the Texas holothurians described in this paper.

MODERN HOLOTHURIANS

Since the most common holothurians are conspicuous animals, not infrequently thrown up on shores after storms, it is not surprizing that man has been familiar with these creatures for many centuries. It is generally supposed that holothurians are the marine animals which Aristotle described under the name ὁλοθούριον, the designation from which their present scientific name has been derived. Certainly it was Pliny who used the name "*Cucumis marinus*," or sea cucumber, for a species of *Cucumaria*, and is thus responsible for the very appropriate common designation of the class today. Belon in 1553, however, was the first to give a detailed description of a holothurian and to point out the affinities of the class to the starfishes and sea-urchins. A few years later Rondelet gave figures of two species, and Bohadsch, Pallas, Fabricius, Cuvier and others greatly increased the systematic and anatomical knowledge of the group in the later part of the eighteenth century (9).

GENERAL DESCRIPTION

The holothurians are stubby, worm- or cucumber-like creatures, varying in length from less than an inch to more than three feet. In general appearance they are very different from the ordinary representatives of the echinoderma, but nevertheless, they have the ambulacral zones and other characteristic features of that phylum. They constitute a fairly sharply defined group of marine invertebrates that is represented in modern seas by about 750 known species. They are especially abundant in tropical waters, but occur in temperate and polar seas as

well; many of them form a part of the benthos, some, indeed, being found as high as high-water mark, but others have been dredged from depths as great as 2900 fathoms.

Holothurians are characterized by an anterior and essentially terminal mouth with a circumoral ring of tentacles, by a posterior and nearly terminal anus, and by the apparent superposition of marked bilaterality upon their fundamental pentamerous symmetry. Many of them possess tube-feet, or pedicles; others have conical processes, or papillae, devoid of suckers. Some have their ambulacral zones so close together that they form a sort of sole upon which the creature creeps, but some genera, such as *Synapta* and *Caudina*, are entirely without tube-feet. Some move by means of the suctorial podia, but others move like the worms, by alternate extensions and contractions of the body. Like many worms, also, the holothurians live on organic material which they extract from the sand and mud passed through the looped alimentary tract. Powerful longitudinal and transverse muscles enable the creatures to alter their shape in a remarkable fashion. In fact, when confined to stale water they essentially turn themselves inside out as though from nausea; or their violent muscular contractions may cause the viscera to be ejected through breaks in the body wall. For these and many other reasons quite beyond the scope of this paper, the holothurians have always been of great interest to the zoologist. Their future potential importance to the paleontologist results chiefly from the fact that their body wall is generally beset with calcareous particles, which have been found (though heretofore quite generally unrecognized or disregarded) in the strata of several geologic periods. (For details of anatomical structure see fig. 1.)

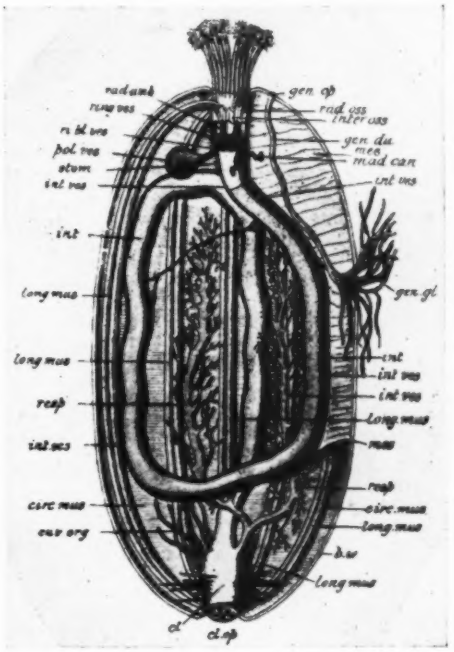

FIG. 1. Internal organs of a modern holothurian seen with body wall divided along mid-dorsal surface (after Leuckart).

b. w. body-wall; *circ. mus.* circular muscle layer; *cl.* cloaca; *cl. op.* cloacal opening; *cuv. org.* Cuverian organs; *gen. op.* genital opening; *gen. du.* genital duct; *gen. gl.* genital gland; *int.* intestine; *inter. oss.* interambulacral ossicals; *int. ves.* intestinal haemal strands; *long. mus.* longitudinal muscles; *mad. can.* madreporic canal; *mes.* mesentery; *pol. ves.* Polian vesicle; *rad. amb.* radial ambulacral vessel; *rad. oss.* radial ossicles; *ri. bl. ves.* ring strand of haemal system; *resp.* respiratory trees; *ring. ves.* ring-vessel of ambulacral system; *stom.* stomach.

CALCAREOUS DEPOSITS

The calcareous bodies of the Holothuroidea are usually microscopic,

but plates several millimeters across occur. Their shapes and sizes differ to such an extraordinary degree in the various genera and species that they constitute one of the fundamental bases for classification in the group. Indeed, the plates assume such unusual forms that we are convinced that many of them, although observed by the micropaleontologist, have been looked upon as indeterminate objects.

The simplest calcareous deposits are minute, irregular grains known as *miliary granules*. Somewhat larger curved or nearly straight spicules, which may be widened or perforated at the ends, commonly occur in the pedicles, papillae and tentacles, and are designated as *supporting rods*. Irregularly branched calcareous particles in some parts of the body wall are known as *rosettes*, or if the deposits assume the shape of more or less regularly perforated discs they are designated as *plates*. Plates with definite projections rising from their middle are known as *tables*, the base being designated as the *disc* and the projection the *spire*.

Other deposits have shapes singularly like common modern objects such as *anchors*, *baskets*, *cups*, *wheels*, *hooks*, and others, from which objects the names of the particles usually are derived. In addition to these

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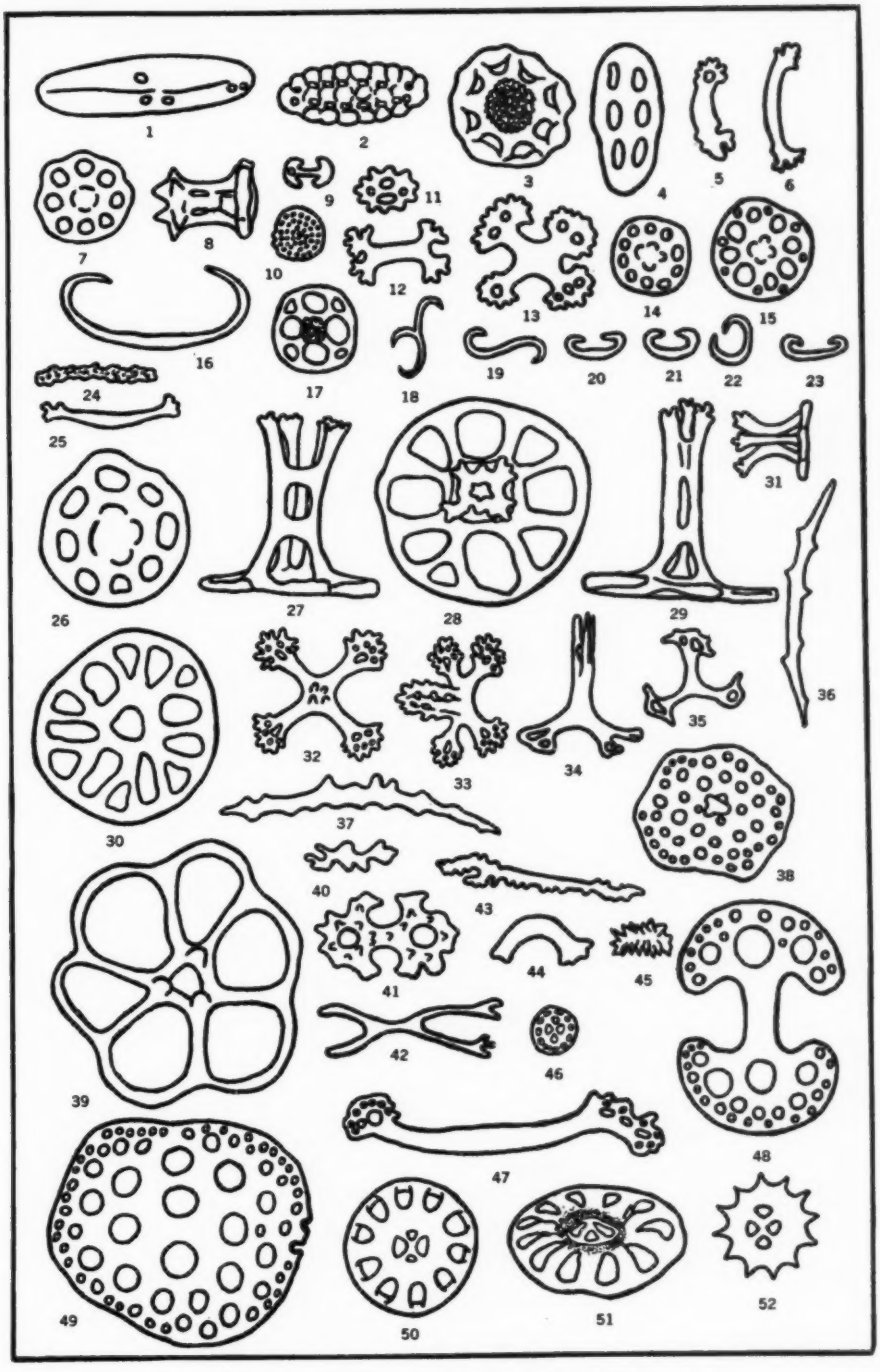
EXPLANATION OF PLATE 15

All figures are magnified 250 diameters unless otherwise stated.

FIGS. 1–2—*Holothuria cubana* Ludwig 1, Supporting plate from podium. 2, Large dorsal button.
3—*Holothuria pseudofossor* Deichmann. Table from body wall of adult.
4—*Holothuria impotiens* (Forskall). Button.
5, 6—*Holothuria globerrima* Selenka. Rods from integument.
7—*Holothuria parvula* (Selenka). Juvenile table.
8—*Holothuria floridana* Pourtales. Table with spire.
9—*Holothuria atra* (Jaeger). Rosette of unusual shape.
10, 11—*Holothuria mexicana* Ludwig. Biscuit-shaped plates.
12, 13—*Actinopyga aggassizi* (Selenka). Plates from body wall.
14, 15—*Stichopus badionotus* Selenka. Discs of tables from adults.
16, 17—*Stichopus macroparenthesis* Clark. 16, C-shaped body. 17, Table from adult.
18, 19—*Stichopus chloronotus* Brandt. 18, Modified C-shaped body. 19, S-shaped particle.
20, 25—*Astichopus multifidus* (Sluiter). 20–23, C-shaped bodies. 24, 25, Supporting rods from tentacles.
26–28—*Mesothuria verrilli* (Théel). 26, Disc of table. 27, Lateral view of juvenile table with spire. 28, Disc of table from young specimen.
29–30—*Mesothuria rugosa* Hérouard. 29, Lateral view of table with spire. 30, Disc of table.
31—*Mesothuria marrocana* Perrier. Table from body wall.
32–33—*Bathyplotes natans* (Sars). Cross-shaped tables.
34–36—*Synallactes alexandri* Ludwig. 34, Stool-like body with spire, ×160. 35, Tri-radiate body, ×160. 36, Spined supporting rod, ×160.
37–38—*Amphigymnas bahamensis* Deichmann. 37, Supporting rod. 38, Plate or table with reduced spire.
39—*Zygothuria lactea* (Théel). Disc of table.
40–43—*Deima blakei* Theel. 40, Irregular rod. 41, Irregular plate from near tentacles. 42, 43, Deposits from wall of genital organs.
44–45—*Orphnurgus asper* Théel. Rods from body wall.
46—*Laetmophasma fecundum* Ludwig. Small wheel, ×160.
47–49—*Oneirophanta affinis* Ludwig, 47, Supporting rod, ×60. 48, Two-ended plate, ×60. 49, Large plate, ×60.
50–52—*Laetmogone theeli* Ludwig. 50, Wheel, ×160. 51, Wheel seen from side, ×160. 52, Wheel with spokes, but no rim, ×160.



Croneis and Mc Cormack—Fossil Holothuroidea

deposits of the skin, tentacles, and feet, there are in some holothurians five calcareous plates surrounding the anus. These are known as *anal teeth*. There is also in most genera a circumesophagal ring of ten plates known as the *calcareous* or *dental ring*. Five of these plates serve as points of attachment for the radial muscles, and are therefore designated as *radials*. The plates which alternate with them are *interradials*. The size and shape of these deposits vary considerably, some plates being characterized by conspicuous posterior prolongations.

Most of the variations in size and shape exhibited in the deposits of modern holothurians are illustrated on accompanying plates 15 to 17, and described under the heading "Classification." The figures have been carefully selected and redrawn from a number of zoological papers with a view toward showing rather completely the gamut of diversity which may be looked for in fossil holothurian deposits. Naturally, however, it has been impossible to include all the modern genera; and some of the genera depicted show a range of spicular variation greater than that indicated by the figures.

CLASSIFICATION

The classification of the holothurians still is in an unsatisfactory condition. Thus, although the outline arrangement of principal genera which follows has the advantage of being readily understandable, phylogenetically it may not bear the most careful scrutiny. The main features of the classification have been borrowed from many writers, chiefly from Deichmann. In addition we have prepared, for the benefit of the paleontologist who does not have ready access to the zoological literature needed for such a compilation, a skeletal diagnosis of most of the important genera. It must be remembered, however, that these spicular variations, significant as they may be to the paleontologist, are of secondary consequence to the zoologist when compared to the anatomical and structural features of the modern holothurians, upon the basis of which the classification largely has been erected.

I. Order ASPIDOCHIROTA Grube, 1840

Deposits, when present, derived from primary crosses or pointed rods. In some genera tables or their derivatives occur, having originated from the crosses.

1. Family HOLOTHURIIDAE Ludwig, 1894

Deposits of various kinds such as tables, buttons, grains, rods, and rosettes, but no C-shaped spicules.

Genus HOLOTHURIA Linnaeus, 1758

Plate 15, figures 1–11

No anal teeth. Tables, and spired tables, button, and other types of deposits, numerous and complex.

Genus ACTINOPYGA Bronn, 1860

Plate 15, figures 12, 13

Anal teeth present. Spicules small, generally dichotomously branched, or spinous rods. No tables or buttons.

2. Family STICHOPODIDAE Haeckel, 1896 (Emend. Deichmann)

Holothurians intermediate in position between the Holothuriidae and the Synallactidae. Deposits tables, granules, C-, S-, or O-shaped, or irregularly curved rods.

Genus STICHOPUS Brandt, 1835

Plate 15, figures 14–19

Tables, or perforated plates representing discs of partly resorbed tables, are abundant. Granules absent or rare. Supporting rods present.

Genus THELENOTA Brandt, 1835

No tables or perforated plates, but many granules and dichotomously branched, slender rods.

Genus ASTICHOPUS Clark, 1922

Plate 15, figures 19–25

No tables or perforated plates, but many granules in groups accompanied by small C-, S-, or O-shaped, or irregularly curved rods.

3. Family SYNALLACTIDAE Ludwig, 1894

Deposits present or essentially absent. When present developed as tables or their derivatives, many with complicated spires. Supporting rods may or may not be present.

Genus PSEUDOSTICHOPUS Théel, 1882

Deposits rare or wanting.

Genus BENTHOTHURIA Perrier, 1901

Deposits wanting?

Genus MESOTHURIA Ludwig, 1894

Plate 15, figures 26–31

No supporting rods, deposits being exclusively tables which are either tri- or quadriradiate.

Genus BATHYPLOTES Oestergren, 1898

Plate 15, figures 32, 33

Deposits in the form of tables with cross-like discs and spires of four rods usually with cross-beams.

Genus PELOPATIDES Théel, 1886

Deposits simple triradiate or quadriradiate, smooth or spinous rods with slightly branched tips. Deposits wanting in some species.

Genus SYNALLACTES Ludwig, 1894

Plate 15, figures 34–36

Deposits usually cross-shaped bodies with a simple, in some cases, bifid spine.

Genus AMPHIGYMNAS Walsh, 1891

Plate 15, figures 37, 38

Deposits large, derived from tables; spire in some cases reduced or absent, but typically of three or four pillars and with one or two cross beams. Supporting rods present.

Genus ZYGOTHURA Perrier, 1898

Plate 15, figure 39

Calcareous deposits exclusively tables of tri- or quadriradiate type.

Genus PARORIZA Hérouard, 1902

No deposits.

II. Order ELASIPODA Théel, 1882

Calcareous deposits in the form of rods wheels, dichotomously branched

rods, short, broad rods, pointed rods with long vertically directed spines, simple perforated plates, and four-armed deposits ordinarily with outer projections.

1. Family DEIMATIDAE Théel (*partim*)

Deposits plates or large dichotomously branching rods, or short, stubby rods. No wheels.

Genus DEIMA Théel, 1882

Plate 15, figures 40–43

Crowded irregularly rounded perforated plates, and delicate spectacle-shaped or simple, smooth to slightly spinous rods.

Genus ORPHNURGUS Théel, 1882

Plate 15, figures 44, 45

Deposits smooth or spinous rods in some cases dichotomously branched or modified into large solid ellipsoids.

Genus ONEIROPHANTA Théel, 1882

Plate 15, figures 47–49

Deposits irregularly rounded and perforated plates and in some cases elongate rods.

2. Family LAETMOGONIDAE Ekman, 1926

Deposits chiefly wheels, but cruciform bodies and rods also occur.

Genus LAETMOGONE Théel, 1882

Plate 15, figures 50–52; Plate 16, figure 1

Deposits are abundant rather flat wheels and scattered spicules or cruciform bodies.

Genus BENTHOGONE Koehler, 1896

Calcareous bodies as supporting rods and extremely vaulted wheels.

3. Family PSYCHROPODIDAE Théel, 1882

Deposits derived from pointed rods which form crosses or four-

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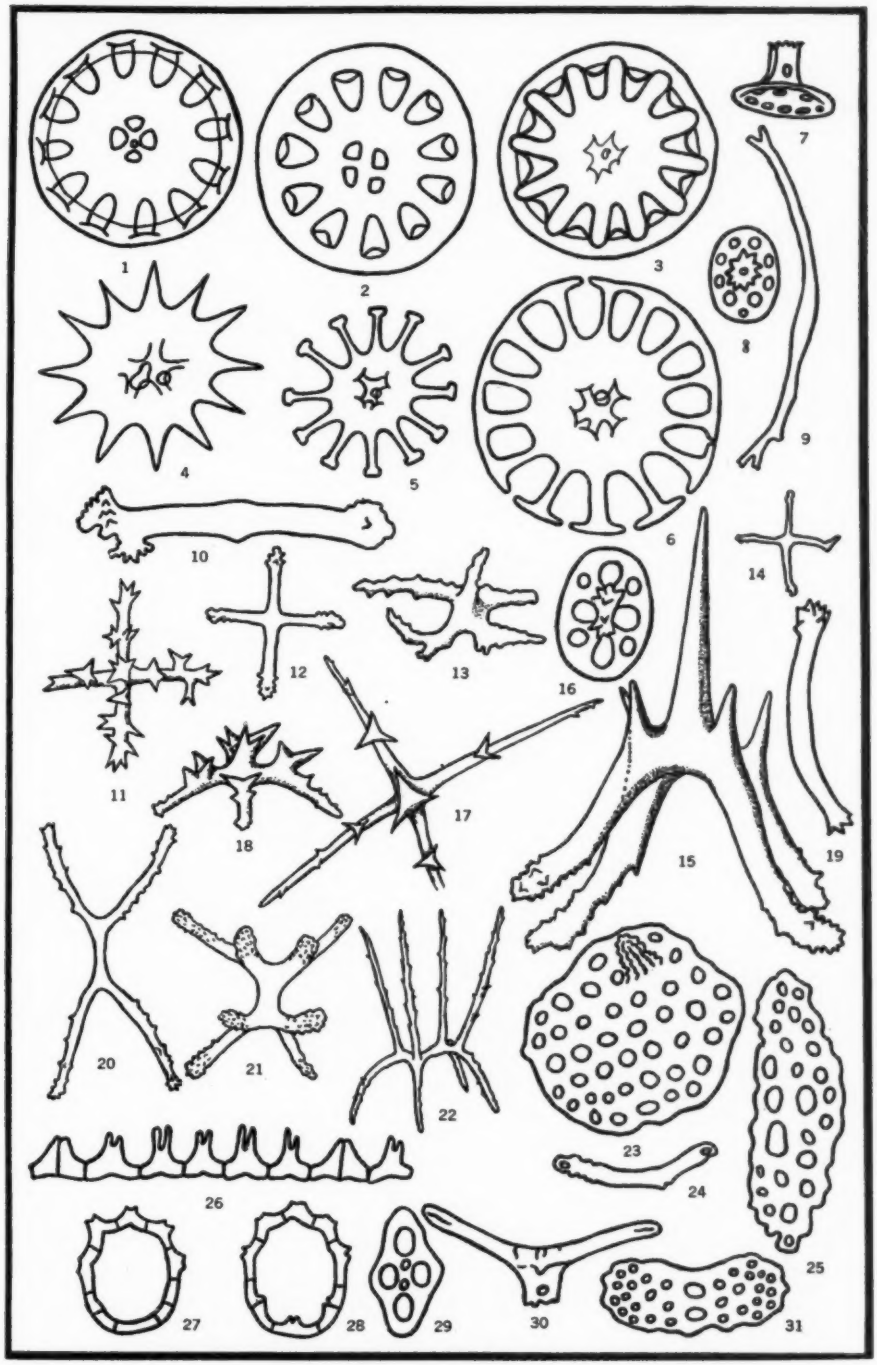
EXPLANATION OF PLATE 16

All figures magnified approximately 250 diameters unless otherwise stated.

FIGS. 1—*Laetmogone theeli* Ludwig. A large wheel, ×160.
2–6—*Laetmophasma fecundum* Ludwig. 2, 3, Wheels, ×160. 4–6, Wheels with the rim absent or in various stages of development, ×160.
7, 8—*Phyllophorus aculeatus* Ludwig. Stool-like bodies seen from the side and from above, ×160.
9, 10—*Benthodytes sanquinolenta* Théel. 9, Supporting rod, ×240. 10, Supporting rod, ×60.
11—*Euphronides verrucosa* Ludwig. Spinous cross-like body.
12–15—*Euphronides tanneri* Ludwig. 12, A cross from the intestinal wall, ×60. 13, A modified cross from the genital organs, ×160. 14, A cross from the wall of an intestinal blood vessel, ×60. 15, A modified cross, ×160.
16—*Phyllophorus destichodus* Deichmann. A table with spire seen from above, ×250.
17—*Psychropotes dubiosa* Ludwig. Modified spinous cross, ×160.
18–19—*Psychropotes raripes* Ludwig. 18, Modified spinous cross, ×160. 19, Supporting rod, ×160.
20, 21—*Peniogone intermedia* Ludwig. Cross-shaped bodies, ×160.
22—*Scotonassa gracilis* Ludwig. Modified cross-like body, ×160.
23—*Echinocucumis hispida* (Barrett). Medium-sized plate with eccentric spire, ×250.
24—*Sphaerothuria talismani* (Perrier). Rod from tentacle, ×250.
25—*Sphaerothuria asperrima* (Théel). Plate from tentacle, ×250.
26–28—*Sphaerothuria bitentaculata* Ludwig. Three views of the calcareous ring, ×7.
29—
30–31—*Cucumaria pulcherrima* (Ayres). 30, Elongate table, ×250. 31, Plate from near end of appendage, ×250.



Croneis and Mc Cormack—Fossil Holothuroidea

armed bodies with inwardly curved arms.

Genus BENTHODYTES Théel, 1882

Plate 16, figures 9–10

Deposits either simple pointed spinous rods or large cross-shaped bodies with curved spinous arms and usually with a strong variable outer projection.

Genus EUPHRONIDES Théel, 1882

Plate 16, figures 11–15

Deposits four-armed bodies with a conical central projection and four conical spines at the bases of the long uncurved arms.

Genus PSYCHROPOTES Théel, 1882

Plate 16, figures 17–19

Calcareous deposits spinous cross-shaped bodies of large size with prominent outer central projection, and smaller cross-shaped bodies with reduced spine.

4. Family CYCLIONIDAE Hérouard, 1923

This family includes *Enypniastes*, *Europlastes*, and *Pelagothuria*, all of which are characterized by a complete lack of calcareous deposits.

5. Family ELPIDIIDAE

Deposits pointed rods or their derivatives, and four-armed bodies with one to four outer projections which are derived from primary crosses. Wheels rare.

Genus ELPIDIA Théel, 1882

Deposits slender straight rods with three straight arms projecting from a point near each end. Small hat-like wheels, rare.

Genus IRPA Danielssen and Koren, 1877

Calcareous deposits in the form of straight, curved, simple, or branched rods.

Genus KOLGA Düben and Koren

Either five or ten rods in each piece of the calcareous ring; rosettes, perforated plates, and C-shaped bodies also present.

Genus ELLIPINION Hérouard, 1923

Calcareous deposits three-armed spicules, straight rods with spinous ends, and C-shaped bodies in some cases with a vestige of the third arm on the convex side.

Genus PERRIAMMA Perrier, 1901

Calcareous deposits in the form of triradiate bodies and large spinous simple or dichotomously branched rods.

Genus PERRIAGONE Théel, 1882

Plate 16, figures 20, 21

Deposits derived from primary crosses with four more or less strongly inward bent arms, and four outer projections. Deposits smooth or covered with fine spines.

Genus SCOTOANASSA Théel, 1882

Plate 16, figure 22

Deposits four-armed with four outer projections.

III. Order DENCROCHIROTA Grube, 1840

Calcareous deposits variable in the form of rods, baskets, buttons, plates, and tables.

Genus PHYLLOPHORUS Grube, 1840

Plate 16, figures 7, 8, 16

Deposits usually tables with two or four rods in the spire; rosettes and perforated plates also occur but no supporting rods.

Genus ECHINOCUCUMIS Sars, 1859

Plate 16, figure 23

Deposits large circular perforated plates, most of which are marked by an eccentric spire composed of several pillars with irregular cross beams. Perforated rods also occur.

Genus SPHAEROTHURIA Ludwig, 1894

Plate 16, figures 24–28

Deposits large circular perforated plates with a strong central spire of several pillars, and smaller plates with simple spire.

Genus CUCUMARIA Blainville, 1834

Plate 16, figures 30, 31;
Plate 17, figures 1, 2, 24, 25

Deposits variable; baskets, plates, tables with simple to fairly complex spires, or knobs, and supporting rods occur. Many of the plates have but four holes. The radials of the calcareous ring in some cases have posterior prolongations.

Genus THYONE Oken, 1815

Plate 17, figures 3–8

Calcareous deposits varied. Tables, knobbed buttons, regular and irregular discs, simple and complex spires, elongate perforated plates, baskets and supporting rods occur in the various species. Perforations of deposits usually large and few in number.

Genus PENTACTA Jaeger, 1833

Plate 17, figure 9

Deposits of very hollow baskets, knobbed buttons, rosettes, triangular or irregular plates, and strong supporting rods.

Genus PSEUDOCOLOCHIRUS Deichmann, 1930

Plate 17, figure 14

Deposits rare but similar to those in *Pentacta*.

Genus PSOLUS Oken, 1815

Plate 17, figures 15–17

Deposits varied. Small four-spoked cups, four-holed plates with small pearl-like marginal knobs, complicated reticulated bodies, and irregular, perforated plates with openings of various sizes occur.

Genus THYONEPSOLUS Clark, 1901

Plate 17, figure 10

Deposits perforated plates and cups, hourglass-shaped tables and complicated tower-like tables.

IV. Order MOLPADONIA Haeckel, 1896

Calcareous deposits commonly tables, fusiform rods, or perforated plates, but anchors also occur. No wheels or sigmoid bodies. Phosphatic bodies commonly present.

Genus MOLPADIA Cuvier, 1817

Plate 17, figures 11–13, 18–23

Calcareous deposits tables, incompletely perforated plates fusiform rods. Anchors occur in connection with simple irregular plates, or groups of plates which are racket-shaped.

The latter are more common in young individuals.

Genus CAUDINA Stimpson, 1853

Plate 17, figures 26, 27, 42, 43

Calcareous deposits varied. Large tables with four central and eight to ten outer holes common; four-spoked discs with marginal knobs, tables with varied spires, buttons and flattened, closed baskets also are known.

V. Order APODA Brandt, 1835

Calcareous bodies; anchors, plates, wheels or sigmoid bodies. No tables occur.

1. Family SYNAPTIDAE Oestergren, 1898

Deposits anchors, plates, and irregularly curved rods.

Genus EUAPTA Oestergren, 1898

Plate 17, figures 29–32

Anchor stock branched, arms smooth, vertex knobbed. Anchor plates with large central perforations and six or seven dentate surrounding holes.

Genus SYNAPTULA Oersted, 1849

Plate 17, figure 33

Anchor stock finely toothed; not branched, arms smooth, vertex slight-

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EXPLANATION OF PLATE 17

All figures magnified approximately 250 diameters unless otherwise stated.

FIGS. 1, 2—*Cucumaria nina* Deichmann. 1, Flattened basket. 2, Irregular plate.
3—*Thyone belli* Ludwig. Rosette from introvert.
4—*Thyone fusus* (O. F. Müller)? Table from body wall.
5, 6—*Thyone micropunctata* Sluiter. 5, Modified supporting rod. 6, Normal button.
7—*Thyone pervicax* Théel. Shallow basket
8—*Thyone cognita* Lampert. Modified plate.
9—*Pentacta pygmaeus* (Théel). Basket.
10—*Thyonepsolus braziliensis* (Théel). Hourglass-like deposit from dorsum.
11–13—*Molpadia musculus* (Risso). 11, Racket-shaped deposit. 12, Fusiform rod from tail. 13, Table.
14—*Pseudocolochirus mysticus* Deichmann. Large supporting rod.
15—*Psolus complicatus* Deichmann. Plate from sole.
16—*Psolus operculatus* (Pourtales). Plate from sole.
17—*Psolus pourtalesi* Théel. Plate from sole.
18, 19—*Molpadia oolitica* Verrill. Modified tables from body wall.
20, 21—*Molpadia blakei* (Théel). 20, Table from tail. 21, Spire.
22—*Molpadia agassizi* (Théel). Large plate.
23—*Molpadia musculus* (Risso). Modified fusiform deposit from body wall.
24, 25—*Cucumaria pentactes* O. F. Müller. Basket-like deposits.
26–27—*Caudina obesacauda* Clark. Four-spoked buttons.
28—*Myriotrochus vitreus* (M. Sars). Wheel, ×140.
29–32—*Euapta godeffroyi* (Semper). 29, 30, Supporting rods from tentacles, ×140. 31, Anchor plate, ×140. 32, Anchor, ×140.
33—*Synaptula hydriformis* (Lesueur). Anchor, ×140.
34, 35—*Leptosynapta gallienii* (Herapath). 34, Anchor-plate from anterior part of body, ×140. 35, Anchor from anterior part of body, ×140.
36—*Leptosynapta multipora* Clark. Anchor plate from anterior part of body, ×140.
37—*Leptosynapta circopatina* Clark. Anchor plate, ×140.
38—*Protankyra ludwigi* (Sluiter). Perforated accessory plate, ×200.
39—*Protankyra similis* (Semper). Anchor, ×140.
40—*Chiridota laevis* (Fabricius). A wheel.
41—*Myriotrochus rinkii* Steenstrup. Wheel in early stage of development.
42, 43—*Caudina arenata* Gould. 42, Wheel, ×200. 43, A series illustrative of the various stages of development of the calcareous tables, ×185.

Croneis and Mc Cormack—Fossil Holothuroidea

ly knobbed. Anchor plate with large central perforation and six outer, somewhat dentate perforations.

Genus SYNAPTA Eschscholtz, 1829

Anchor as in *Synaptula;* anchor plate sub-rectangular or irregular, longer than wide with seven or eight large and numerous small perforations.

Genus LEPTOSYNAPTA Verrill, 1867
Plate 17, figures 34–37

Anchor stock finely toothed, but unbranched. Arms with outwardly projecting teeth on outer edge, vertex smooth. Anchor plates elongate.

Genus PROTANKYRA Oestergren, 1898
Plate 17, figures 38–39

Anchor stocks more or less branched, arms serrate, vertex smooth. Anchor plates without a handle, and with numerous irregular holes.

2. Family CHIRIDOTIDAE Oestergren, 1898

Calcareous deposits six-spoked wheels and sigmoid or C-shaped bodies with curved or straight rods.

Genus CHIRIDOTA Eschscholtz, 1829
Plate 17, figure 40

Deposits six-spoked wheels and small curved rods with enlarged ends. No sigmoid bodies.

Genus TOXODORA Verrill, 1867

Deposits minute plates in the form of bows or parentheses with uncurved ends. No wheels.

3. Family MYRIOTROCHIDAE Oestergren, 1898

Deposits wheels of eight or more spokes and sigmoid and C-shaped bodies.

Genus MYRIOTROCHUS Steenstrup, 1851
Plate 17, figures 28, 41

Calcareous deposits consist of wheels with ten to twenty-five spokes, and with numerous large, flat, sharp teeth projecting horizontally inward from the rim. Other types rare or entirely wanting.

FOSSIL HOLOTHURIANS

The written paleontologic history of the holothurians is at present short and simple. Fossils are of two types: (1) casts or impressions of all or parts of the body, and (2) calcareous skeletal elements of a great variety of shapes. From the very nature of the animal it follows that casts or impressions of the body are, and always will be, extremely rare paleontologic objects. The scattered calcareous deposits, however, are much more common as fossils than hitherto has been supposed. A synoptic discussion of the two types follows.

IMPRESSIONS OR CASTS

Dr. E. Rüppell (59), as early as 1829, described and figured as a holothurian an elongate sack-like body from the lithographic limestone of Solenhofen, Bavaria. Zittel's (76) discussion of this subject is somewhat ambiguous as is well indicated by the fact that Etheridge (38) construed it to signify that Rüppell's specimen

might, in Zittel's estimation, be placed in Geibel's (41) genus *Protoholothuria*, whereas H. L. Clark (24) is of the opinion that Zittel regarded Rüppell's material as of problematical nature. As a matter of fact, Zittel tentatively suggested that the specimen in question might represent the body of a "naked cephalopod," but really regarded both Geibel's and Rüppell's specimens as "problematiches Körper." The latter designation seems proper enough for Rüppell's material, but the writers agree with H. L. Clark (24) that Geibel's description and figures of holothurians (also from the Solenhofen beds) seem authentic. Geibel has further strengthened his case by finding calcareous bodies on the surfaces of his holothurian impressions.

Fric (39), in 1893, described from the Cretaceous of Bohemia an indeterminate worm-like structure which he tentatively suggested was the intestinal tract of a holothurian.

Broili (32) recently has described and figured another holothurian from the upper Malm of Franconia. In this particular specimen, which he has designated as *Pseudocaudina brachyura*, the body outline is very well preserved (fig. 2). Broili, who refuses to accept Giebel's genus *Protoholothuria* as including anything more than indeterminate worm-like bodies, states that with the exception of Walcott's (28) mid-Cambrian holothurians, his *Pseudocaudina* is the only fossil representative of this class in which the body form is preserved. Still another possible European instance of the preservation of the body outline of a holothurian, however, is recorded by Simonelli (63), who has figured a problematical worm-like fossil, *Lorenzinia*, which he suggests may represent a part of a fossil *Pelagothuria;* but there is little of a positive character in Simonelli's description or figure to support his suggestion.

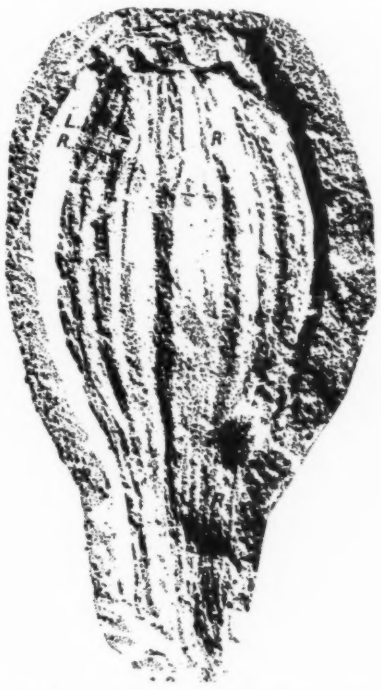

FIG. 2. *Pseudocaudina brachyura* Broili, ×⅔. (After Broili in *Sitzungsberichte der Bayerischen Akademie*, München). Upper Jurassic. One of the better preserved of the few fossils interpreted as representing the body form of an ancient holothurian.

The only North American record of fossil holothurians with features of the body preserved is that of the apparently well diversified mid-Cambrian fauna described by Walcott (28). The existence of such a holothurian fauna, however, was vigor-

ously denied in 1912 by Dr. H. L. Clark (24) who said, in part,

> If *Eldonia* (the best represented of Walcott's genera) is a holothurian, it becomes virtually impossible to define the class, except in terms of the alimentary canal. Indeed, if *Eldonia* is a holothurian, the echinoderms themselves can be defined in no other terms, for *Eldonia* lacks every single character which

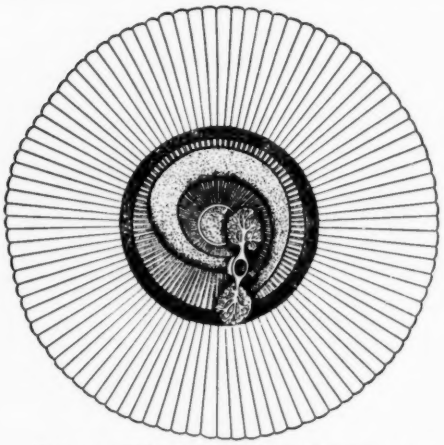

FIG. 3. *Eldonia ludwigi* Walcott, as restored by A. H. Clark in the *Zoologischer Anzeiger*.

> justified the customary view that holothurians are echinoderms. It is far less of a strain, on my credulity to believe that *Eldonia*, whose extraordinary nature I have no inclination to deny, is some sort of a coelenterate with a commensal worm inside or under the sub-umbrella, or even that it represents a hitherto unknown phylum, than to believe that it is a holothurian or is connected, save in the remotest way with the echinoderms.
>
> As a final result of my examination of the evidence, I am forced to conclude that there is no sufficient justification for the belief in a Cambrian holothurian fauna. . . .

Dr. A. H. Clark (22), however, had in 1912 accepted Walcott's findings as *bona fide* and had published a restoration of *Eldonia* (see fig. 3). It was natural, therefore, that he should (in 1913) rise to the defense of Walcott's work, and criticize Dr. H. L. Clark's comments. In a philosophical paper, in which the Cambrian genera in question are discussed at some length, he disposes of them as follows: *Laggania* and *Louisella* are regarded as belonging to the family Elpidiidae, a modern group of essentially abyssal holothurians; *Eldonia* forms the basis for a new family, Eldoniidae, which is regarded as closely related to the Elpidiidae; *Mackenzia* is described as an actinian belonging to the family Edwardsiidae; and *Lorenzinia*, Clark parenthetically adds, "is undoubtedly the cast of a part of a medusa, as anyone acquainted with the literature on the fossil medusae can see."

In the 1913 revision of the Zittel-Eastman textbook, H. L. Clark, in the section dealing with the holothurians, seems to recognize the authenticity of Walcott's holothurian material. A footnote, however, indicates that H. L. Clark did not contribute "the paragraph in regard to Cambrian representatives of the class," and in a letter to Mr. Croneis dated March 4, 1931, Dr. Clark says,

> That footnote absolves me from all responsibility with reference to the comments on Walcott's holothurians. I have recently been giving further thought to the matter, and I am just as sure as I was in 1912 that there is not sufficient justification for the belief in a Cambrian holothurian fauna. Until new and much more satisfactory evidence is produced I shall be compelled to maintain this position.

There seems to be little doubt that *Mackenzia costalis** is an actinian and

* Indeed, this is the genus which forms the basis for Raymond's *Edwardsia-Mackenzia* coral theory.

not a holothurian, but further information is needed before *Laggania*, *Louisella*, and *Eldonia* can be classified to the satisfaction of all. *Redoubtia* and *Portalia*, which unfortunately were first described in the popular account of Smithsonian field explorations (28a) that very few paleontologists see, have been refigured in one of Walcott's posthumous publications (28b). These genera, although not certainly holothurians, are more convincing as possible Cambrian representatives of the class than the other and better known forms. Through the kindness of Prof. B. F. Howell we have also been able to study as possible holothurians some of the actual specimens of *Eocoryne geminum*, the problematical mid-Cambrian spicules from New Brunswick which Matthew (27a) tentatively regarded as sponge remains. These fossils, however, throw no certain light on the question of the validity of Walcott's Cambrian genera; in fact, Matthew's determination of these puzzling spicules is probably as good as can be arrived at. One extrinsic point, however, which the present writers feel increases the *plausibility* of the argument that the Burgess shale genera actually represent Cambrian holothurians, is the very considerable diversity of the class at least as early as Chester time.

Still another reputed occurrence of Cambrian holothurians is that at Bray Head, County Wicklow, Ireland, reported in 1912 by Ryan and Hallissy (60). These authors believe that they have a mid-Cambrian fauna somewhat similar to that made known by Walcott, though very much less well preserved. Among other specimens they have found a number which they feel closely resemble Walcott's *Eldonia ludwigi;* and they have, on the basis of this material, proposed a new species, *Eldonia antonii*. There is little or nothing in Ryan and Hallissy's figures, however, to warrant such a comparison, though it is possible that their actual specimens may show more clearly points of similarity to Walcott's material.

CALCAREOUS DEPOSITS*

Von Münster (73), as early as 1843, described and figured from the Jurassic Scyphia limestone of Streitburg an anchor spicule consisting of a long shaft, non-serrated flukes, and a small transverse terminal piece. This he recognized as similar in all respects to the anchor plates of modern Synaptae, and he therefore described it as *Synapta sieboldi*.

Chevalier d'Eichwald (36), in 1860, expressed the opinion in his "*Lethaea Rossica*" that the objects from the Orthoceratite limestone of St. Petersburg, described by Pander as conodonts, were in reality fragments of holothurian spicules. Subsequent work, however, has shown that Pander's view as to the identity of these organisms is the correct one.

Schwager (62), in 1865, described some Jurassic microfossils which he considered to be wheel-like spicules of holothurians. One of these he iden-

* A number of the species discussed under this heading are illustrated on Plates 18 and 19.

tified as *Chirodota* (sic) *sieboldii*, and the other he did not describe specifically. Zittel (76) was of the opinion that these bodies actually were holothurian remains, an opinion shared by the present writers, but Etheridge (38) felt that they had a closer relationship with the Polyzoa.

Terquem, in 1858 (68a), described under the name of *Uncinulina polymorpha*, a Liassic holothurian spicule which he thought was a foraminifera. Again, in 1866, Terquem (69) described as foraminifera a number of holothurian remains from the Lias of L'Indre and Moselle; but Gümbel

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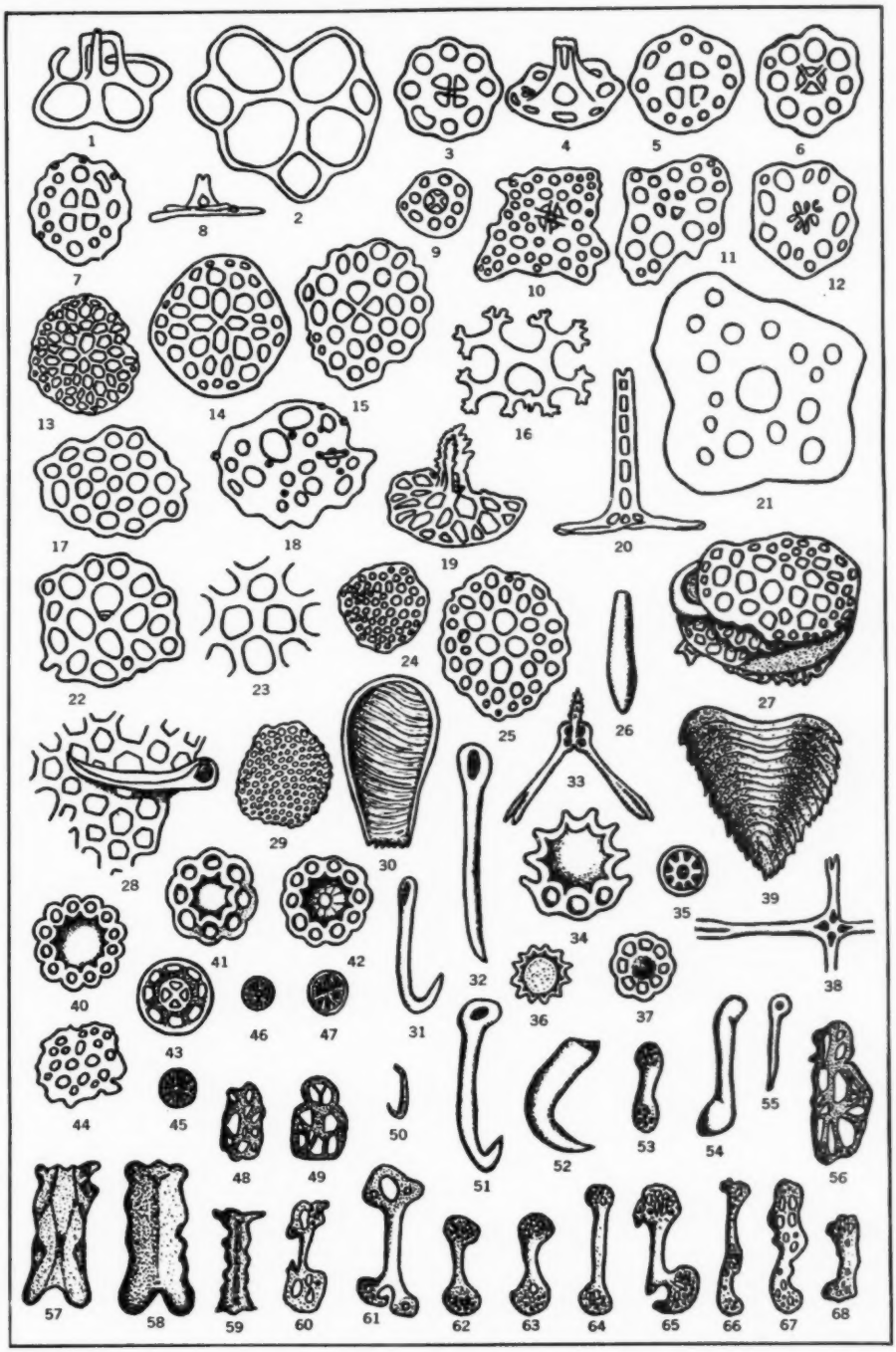
EXPLANATION OF PLATE 18

All figures magnified approximately 250 diameters unless otherwise stated.

FIGS. 1, 2—*Priscopedatus normani* Schlumb. Eocene of Chaussy.
3–6, 9—*Priscopedatus pyramidalis* Schlumb. Eocene of Chaussy.
7—*Priscopedatus propinquus* Schlumb. Eocene of Chaussy.
8, 10—*Priscopedatus multiforis* Schlumb. Eocene of Chaussy.
11—*Priscopedatus anceps* Schlumb. Eocene of Chaussy.
12—*Priscopedatus corolla* Schlumb. Eocene of Chaussy.
13, 14, 20—*Priscopedatus eiffeli* Schlumb. Eocene of Chaussy.
15, 17—*Priscopedatus aspergillum* Schlumb. Eocene of Chaussy.
16—Spicule of a so-called sponge of the type commonly found by Schlumberger associated with the holothurian remains.
18—*Priscopedatus inaequalis* Schlumb. Eocene of Chaussy.
19—*Priscopedatus echinatus* Schlumb. Eocene of Chaussy.
21—*Priscopedatus crassus* Schlumb. Eocene of Chaussy.
22—*Priscopedatus cribellum* Schlumb. Eocene of Chaussy.
23, 25—*Ancistrum nicholsoni* Etheridge. Lower Carboniferous near Fordel, Fife.
24, 29—*Ancistrum*? sp. Plates described by Etheridge as possible "miliary granules" of *A. nicholsoni*. Lower Carboniferous, near Fordel, Fife.
26—Undetermined tooth-like organism from Lower Carboniferous near Fordel, Fife.
27—*Ancistrum nicholsoni* Etheridge. Two plates with "hook" lying between. Lower Carboniferous near Fordel, Fife.
28—*Ancistrum nicholsoni* Etheridge. Portion of a plate with the "hook" attached. Upper Carboniferous, River Avon.
30, 33, 38, 39—Spicules figured by Etheridge, but not named. Fig. 39 was referred to as similar to the body plates of the modern *Cucumaria frondosa*. All from the Lower Carboniferous near Fordel, Fife.
31, 32—*Ancistrum nicholsoni* Etheridge. Two "hooks" interpreted by Etheridge as representing different stages of development. Lower Carboniferous of Fordel, Fife.
34, 36, 37, 40–42—*Protocaudina primaeva* (Etheridge). Specimens showing variation of from 8 to 12 outer perforations. Figs. 34 and 36 are with the rim. Upper Carboniferous of River Avon.
35—*Protocaudina robertsoni* (Etheridge). Lower Carboniferous near East Kilbride, Lanarkshire
43—*Protocaudina traquairii* (Etheridge). Lower Carboniferous near Fordel, Fife.
44—*Psolus*? sp. A plate figured by Pocta from the Cretaceous of Bohemia, ×75.
45–47—Unnamed holothurian wheels from the Lias of Schwabia figured by Issler.
48, 49, 53, 56, 60–68—*Uncinulina polymorpha* Terquem. A variety of spicules from the Schwabian Lias figured by Issler under this name.
50, 51—*Ancistrum issleri* Croneis, n. sp. This new specific name is proposed in honor of Alfred Issler who figured these Liassic spicules simply as "holothurian remains." The two specimens figured are the only representatives of *Ancistrum* that have thus far been found in rocks younger than Paleozoic.
52—Figured by Issler as a possible hook from the tentacles of an ammonite; this may be a Liassic holothurian remain.
54, 55—"Echinoderm remains" figured by Issler from the Lias of Schwabia. These also may be holothurian spicules.
57–59—"Echinoderm remains" figured by Issler which probably are "braces" from the Aristotle's lantern of an echinoid.



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(42), in 1869, described and figured from the Liassic St. Cassian and Raibl beds "Kalkrädchen" of holothurians as well as spicules which he recognized were "Synapta-ähnliche Körper." Some years later Terquem and Jourdy (70) described holothurian remains from the Bathonian of France as "spicules d'Astrophyton," and in 1875, Terquem and Berthelin (71) labeled similar fossils from the middle Lias of Essey-lès-Nancy simply as "spicules de tube ambulacraire de Radiaires." The same writers, however, described wheel-like holothurian plates from the same beds as *Chiridota violacea*, *Hemisphaeranthos florida* and *H. costifera;* and Kübler and Zwingli (49), in describing the foraminifera of the White Jura, list the "Kalkrädchen" of *Chiridota vetusta*, which Waagen (74) as early as 1867 had found in the While Jura of Aubigné.

In 1876, Tate and Blake (68) described holothurian spicules from the Lias of Yorkshire both as "holothuroid spines" and "crinoid segments."

Issler (48), in 1909, listed a number of the above mentioned Jurassic types as present in the Lias of Schwabia. Many of the wheels he tentatively referred to *Chiridota*, but many of the variety of other types of spicules he listed, probably incorrectly, under the old *Uncinulina polymorpha* of Terquem. In addition, Issler has figured a number of problematical bodies which he labels as "sponge needles," "hooks of the tentacles of an ammonite," and "echinoderm remains," some of which very probably are holothurian spicules.

Some years before the publication of Tate and Blake's "Yorkshire Lias," Moore (53), in a paper before the British Association (1872) reported the first discovery of holothurian remains in the rocks of Great Britain. In his communication Moore described, but did not name, minute wheel-like bodies about 1/40 of an inch in diameter which he had collected from the Inferior Oolite and Lias. Although Moore's report is *bona fide*, it is obvious from the foregoing discussion that it is not, as Etheridge (38) said, "the first reliable notice" of the remains of holothurians in "rocks older than the Tertiary."

In 1873, however, Etheridge (37) did report the first *Paleozoic* record of the holothurians. The skeletal remains described were from the Carboniferous strata of the environs of Glasgow. In 1881, Etheridge published a second paper on the holothurians of the Carboniferous of Scotland. This was the first important paper on the fossils of this class (although it apparently has been overlooked by most workers); and even to the present it is one of the very few which treat of fossil holothurians other than incidentally. Noteworthy features of Etheridge's article are his brief discussion of the types of holothurian plates found today, and his description of the fossil forms in the light of the modern variations in the deposits. Etheridge listed the types of fossils found as (1) perforated plates of various sizes, (2) hooks or anchors, (3) wheel-like plates, (4) cross-like bodies, and (5) other spicu-

lar bodies. One of the most common of these is the wheel-like *Cheirodota* (sic) *traquairii*, but the fishhook-like spicules, to which Etheridge gave the name *Achistrum nicholsoni* are not rare.

Pocta (57), in 1885, described a holothurian plate from the Cretaceous of Bohemia as *Psolus? sp.*, and pointed out its similarity to *Psolus phantapus* a modern North Sea form.

Schlumberger (61, 62), in 1888 and 1890, presented to the Geological Society of France the results of his researches on the fossil holothurians of the Eocene Calcaire Grossier. In his papers, which rank with Etheridge's in importance, Schlumberger describes and figures many species of the Apoda, thus showing that at least as early as early Tertiary times the recent families Synaptidae, Chiridotidae, and Myriotrochidae were well differentiated.

In 1893, Woodward (75) again mentioned the occurrence of holothurian remains in the Lias of England, and in 1897, Bell (29) reported the presence of both *Cucumaria* and *Psolus* spicules in the later Tertiary deposits of England. In the same year, Geinitz (40) described a few holothurian remains from the Cretaceous of Mecklenburg.

Spandel (66), in 1898, described a number of holothurian spicules from the Zechstein of Germany. The wheel-like and modified anchor types of calcareous bodies he classified as true holothurians under the names *Chirodota* (sic) *geinitziana* and *Prosynapta eiseliana* respectively. The fishhook-like spicules, however, he designated as *Astrophyton ? permianum*, tentatively, at least, regarding them as the spicules of one of the Cladophiuroida. The above paper was reviewed by Lambert (50) in 1899. Spandel (67) a year later described also some holothurian remains from the upper Oligocene beds of the Mainz Basin.

Peach (56), in 1900, again noted the presence of holothurian spicules in the Carboniferous rocks of Fife, and in the same year, Deprat (34) again recorded them from the Jurassic of the French province of Doubs. A year later, Smith (65) listed Etheridge's *Achistrum nicholsoni* from the Carboniferous strata of the Clyde Drainage Area, but he changed the spelling of the generic name to *Ancistrum*, apparently following a recommendation by Bather in the Zoological Record for 1900. In the same year, Hinterlechner (45) reported *Holothuria* sp. as common in the Cretaceous of eastern Bohemia.

Hall (43), in 1902, supplied the first and only reference to fossil holothurians from Australia, in describing and figuring an Eocene ? wheel-like plate, which, because of its six spokes, probably has been correctly referred to the genus *Chirodota* (sic).

Norman (55), in "Notes on the Natural History of East Finmark" published in 1903, indicated that Schlumberger's *Stueria elegans* is probably a synonym of *Myriotrochus rinkii*. A year later, Madsen (51), in a critical review of a Danish paper by Holst, reported *Psolus fabricii* from the Tertiary of Denmark, and in 1905, Nordman (54) listed the same

species from the Yoldia Clay at Esbjerg.

Hucke (47), in 1905, again listed and figured *Uncinulina polymorpha* Terquem from the Gault of Bartin, Hinterpomerania, and pointed out the similarity of that species to the recent *Chirodota* (sic) *Japonica* von Marenz. Beede (21a), in 1906, figured a number of spicules (from the Spergen limestone of Indiana), which resemble sand-burs or stellate sponge spicules, under the heading "Holothurian Spicules?" These fossils, however, are in shape more like heteractinellid sponge spicules than holothurian deposits.

Marie and Deecke (52), in 1908, added another reference to *Chirodota* (sic) *sieboldi* by listing it from the Jurassic sediments of Haute Sâone, and Upton (72), in 1917, published some "Notes on *Chirodota* (sic) spicules from the Lias and Inferior Oolite" of England. In 1920, Bell (30) cited both *Cucumaria* and *Psolus* in his lists of later Tertiary invertebrates, and four years later, Duvergier (35) recorded the presence of *Echinocucumis*, *Psolus*, and *Oneirophanta* in the Tertiary of Saucats.

In 1927, Hok (46) published the latest European reference to fossil holothurians known to the writers when he described the new genera *Heliodiscoaster*, *Eudiscoaster*, and *Hemidiscoaster*, and suggested their holothurian relationships, though he listed them under the heading "Incertae Sedis."

EXPLANATION OF PLATE 19

All figures are magnified approximately 250 diameters unless otherwise stated.

FIGS. 1–5—*Synapta eocena* Schlumb. Eocene of Chaussy.
6—*Synapta stueri* Schlumb. Eocene of Chaussy.
7—*Synapta renifera* Schlumb. Eocene of Chaussy.
8—*Synapta circularis* Schlumb. Eocene of Chaussy.
9—*Synapta laevigata* Schlumb. Eocene of Chaussy.
10—*Synapta truncata* Schlumb. Eocene of Chaussy.
11–14—*Priscopedatus pyramidalis* Schlumb. Eocene of Chaussy.
15, 16, 19, 21—*Myriotrochus elegans* Schlumb. Eocene of Chaussy. Fig. 16 represents two spokes and a part of the rim enlarged about 400 diameters.
17, 24.—*Theelia undulata* Schlumb. Eocene of Chaussy.
18, 20—*Myriotrochus operculum* Schlumb. Eocene of Chaussy.
22—*Chiridota curriculum* Schlumb.
23—*Chiridota lanceolata* Schlumb. Eocene of Chaussy.
25–27—*Ancistrum permianum* (Spandel). Zechstein. The only Permian occurrence of the genus thus far recorded.
28—*Chiridota ? vetusta* Waagen, (as figured by Queenstedt). White Jura of Aubigné. This form lacks the characteristic six spokes of *Chiridota* and probably belongs to another genus.
29, 38—*Protocaudina geinitziana* (Spandel). Zechstein. Fig. 29 is a cross-section to show the concavo-convex character of the wheel.
30—*Ancistrum? permianum?* (Spandel). Zechstein. A plate figured by Spandel under the name *Astrophyton permianum.*
31–33—Possible holothurian remains interpreted by Spandel as pedicellaria of *Eocidaris keyserlingi* Geinitz.
34—*Chiridota* sp. The only Australian holothurian spicule. Figured from the Eocene of Spring Creek, Victoria, by Hall. Compare with Fig. 23.
35—*Priscopedatus margaritatus* Schlumb. Eocene of Chaussy.
36–37—*Priscopedatus irregularis* Schlumb. Eocene of Chaussy.

Croneis and Mc Cormack—Fossil Holothuroidea

Hanna (27), as late as 1930, first recorded holothurian spicules from North America when he described from the Pennsylvanian and Permian strata of Kansas wheel-like plates under the name of *Laetmophasma* (?) *kansasensis*. Croneis (26), in 1931, indicated that this apparently widespread form was probably the same as that described by Etheridge under the name *Cheirodota* (sic) ? *traquairii*, and that similar if not identical plates had been found in the Chester of Illinois and the Pennsylvanian of Texas. In this article, unfortunately, there were cited as illustrative of deposits of *Laetmophasma fecundum* several figures which actually represent wheels of another holothurian. The fourth line on page 48 of this paper should therefore be altered to read " . . . especially his figures 3 and 11, plate 11," and the next sentence should begin "Figure 11 . . . " The correction of this inadvertence, however, in no way modifies the other statements in the original note.

In addition to the above list of references, Quenstedt (58), Bernard (31), Haekel (44), De Lage and Hérouard (33), Goodrich (9) (in Bather) and H. L. Clark (25) (in the Zittel-Eastman text), have briefly discussed fossil holothurian spicules in their general zoological of paleontological treatises.

Descriptions of some of the well-defined holothurian-spicule faunas of the Gulf States Cretaceous, particularly of the Del Rio, first called to our attention by Helen Jeanne Plummer, will appear in subsequent publications.

GEOLOGIC HISTORY

From the foregoing discussion it is apparent that holothurian spicules, although rarely recognized, nevertheless have been met with in strata ranging in age from early Carboniferous to the later Tertiary; and in addition, Ehrenberg and others have reported them from a number of modern marine clays. We predict that they will be found to be common in the Carboniferous, Jurassic, Cretaceous and Tertiary. In the past, however, they have seldom been reported from Cretaceous strata, they are as yet rare from the Permian, and they are essentially unknown from the Triassic or pre-Carboniferous. We have, however, certain evidence of their occurrence in a number of the Cretaceous formations of the Gulf states, and there is a strong suspicion that some of the rather indeterminate objects from the Devonian Bell shale of Michigan, which we have been studying, will also turn out to be holothurian spicules.

Although the information available is perhaps insufficient, we have ventured to prepare for the Holothuroidea a diagrammatic evolutionary tree on which the geologic history of the class is portrayed. This tentative chart (fig. 4), which really is to be regarded as a sort of progress report, shows the actual geological records as solid lines, and indicates by means of dashes the supposed evolutionary course of the class during those periods in which we have no actual records. The chart is to be considered, however, as a paleontological rather than a zoological contribution,

for although it does indicate that certain groups of holothurians, now regarded as closely related, were distinct fairly far back in geologic history, it does not preclude the possibility of somewhat different evolutionary trends in some of the families.

POTENTIAL STRATIGRAPHIC VALUE

The fact that holothurians are free-swimming (though sluggish) marine creatures, and that their calcareous deposits are of specific importance in the classification of the modern forms, make the fossil deposits interesting

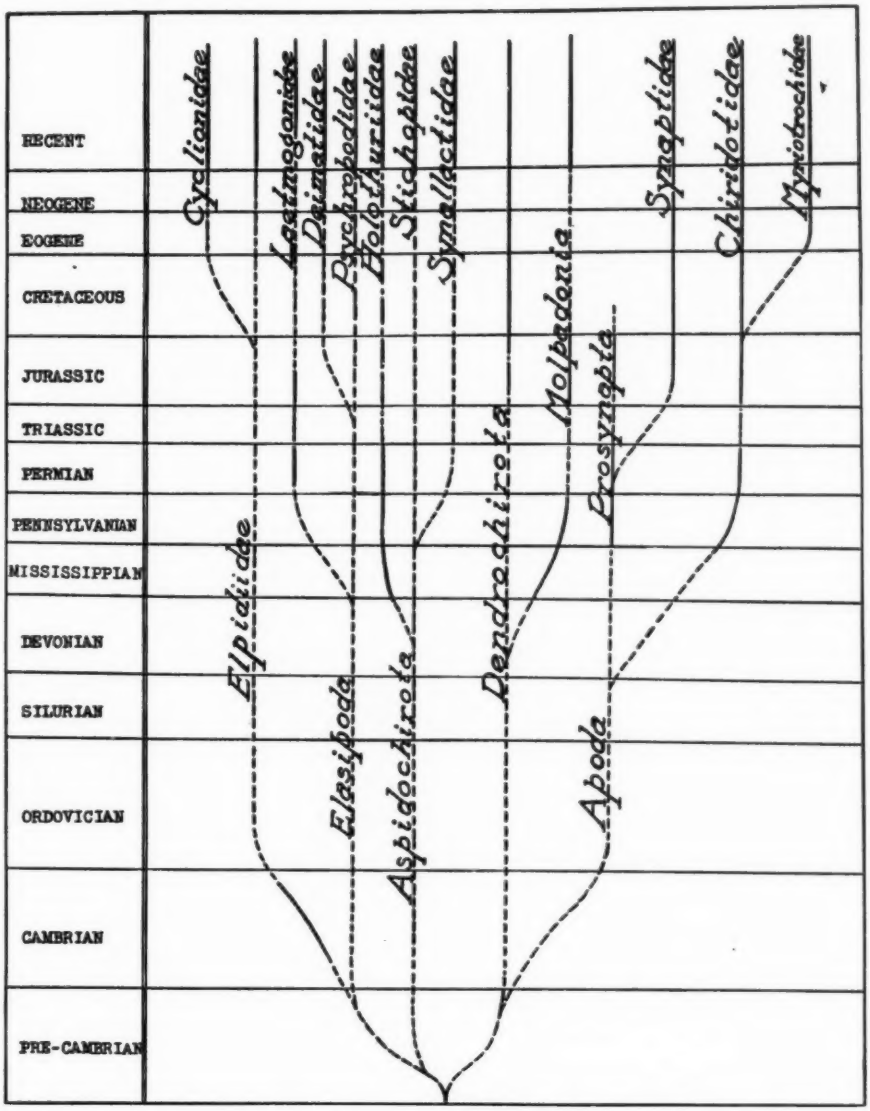


FIG. 4. Evolution of the Holothuroidea.

as potential horizon markers. The calcareous bodies in some species, however, undergo such radical changes during their development (and, in some cases, during their resorption) that they may be of lesser stratigraphic value to the paleontologist than they otherwise would be. Indeed, the very fact that the zoologist is becoming able to elucidate systematic modern holothurian relationships on the basis of the metamorphosis of the calcareous bodies (8) (15) gives definite indication of the difficulties before the paleontologist, who, in some cases, will be unable to determine with certainty whether the scattered fossil skeletal elements have been derived from youthful, immature, adult, or senile individuals. Furthermore, there is an unfortunate, and in some cases baffling, similarity of certain holothurian deposits to echinoid spines and parts of the lantern, ophiuroid plates, crinoid columnals and other parts, brachiopod spines, sponge spicules and bryozoan fragments.

Another feature which prevents the ready usage of *all* skeletal elements of holothurians as index fossils is the fact that some of the deposits, such as the supporting rods, C- and S-shaped bodies, rosettes, and even some types of tables, may be essentially the same in widely different genera. An added complication also is introduced by the great similarity of some of the fossil plates and spicules to those of modern species. Furthermore, since calcareous deposits of markedly different aspect occur in a single holothurian, and as it is essentially hopeless to expect to find complete fossil representatives of the class, it follows that several different specific or even generic terms probably will be given to deposits which may have been formed in various parts of one animal.

In spite of these and other difficulties, it appears from our studies that certain spicules are confined to narrow vertical ranges, and it is probable that the class may be of very considerable stratigraphic importance as microfossils. In order that their true value may be ascertained, however, it will be necessary for micropaleontologists to describe the holothurian faunas of a large number of formations. Until this is done it will be impossible to ascertain which types of skeletal elements have wide geographical and narrow geologic ranges. And in order to carry on the work most rapidly and efficiently the great range of differences formerly permitted for individual species of fossil holothurian spicules must be considerably limited. In fact, if these microscopic objects are to have correllative value they must first be classed as so many different bolts, screws, and nuts, regardless of whether they were made in the same factory and out of the same metal! When the range in types of holothurian deposits in any one set of beds is established, it will be time enough (though even then probably in part futile) to speculate whether or not five or six radically different spicules may have originated in the same animal, and therefore perhaps merit the same specific name.

Pending further study and the accumulation of additional material, only a few of the more easily defined forms are here given generic or specific designations. Much work on fossil holothuroids remains to be done.

DESCRIPTION OF SPECIES

Genus PROTOCAUDINA Croneis, n. gen.

Calcareous, concavo-convex, fossil holothurian discs with four central holes and eight to ten outer perforations. Rim circular or slightly scalloped. Genotype *Cheirodota traquairii* Etheridge.

Remarks. This is the most abunddantly represented genus of holothurian wheels in the Paleozoic. Although described for many years, and by a number of writers, under the genus *Chiridota*, the configuration of the discs makes it impossible to retain the various species under that name.

PROTOCAUDINA TRAQUAIRII (Etheridge)
Plate 20, figures 1, 3–5, 7–11, 14–17, 22–24, 26–28

Cheirodota (?) *Traquairii* ETHERIDGE, *1881*, Proc. Royal Phys. Soc. Edinburgh, vol. 6, p. 196, pl.6, fig. 1.

Laetmophasma (?) *kansasensis* HANNA (part) *1930*, Jour. Pal., vol. 4, p. 413, pl. 40, fig. 3.

Etheridge's description: Concavo-convex wheel-like plates, with a very slightly undulating margin, and a central space occupied by four more or less triangular perforations; outer zone subdivided by eight short septa or spokes into a corresponding number of semicircular or semi-oval perforations, with plain margins. The diameter is about .01 of an inch; the central space is about .0035 of an inch.

Remarks. This general type of holothurian spicule apparently is the most ubiquitous of all the Carboniferous representatives of the class. A glance at Plate 20, however, will at once indicate that there is considerable variety of proportions shown by this group of disc-like plates with four inner and eight outer perforations. That some of these variations are of specific importance cannot be doubted, but until further material comes to hand they will be lumped under Etheridge's species.

P. traquairii has not as yet been reported from the Pennsylvanian sediments of North America except in the Elmdale shale (now classed as basal Permian by the Kansas Geological Survey) near Elmdale, Kansas, and in Europe it has thus far been reported only from the Upper Carboniferous shales of Orchard Quarry, near Glasgow. It is common, however, in the Chester of Illinois, particularly in the Paint Creek and Glen Dean formations, and it also occurs in beds designated as "lower Okaw."

A typical Glen Dean specimen from a sample collected ¾ mile west of "School No. 9," about 3 miles southwest of Vienna, has the following measurements:

Diameter of disc	0.3667 mm.
Thickness of rim	0.0298 mm.
Width of spokes at junction with rim	0.03 mm.
Greatest dimension of central holes	0.0417 mm.
Average greatest width of outer holes along rim	0.0792 mm.
Average greatest height of outer holes	0.0625 mm.

Other individuals from the Glen Dean generally range from 0.28 to 0.38 mm in diameter, but one perfect specimen has been measured which

has a greatest dimension of 0.2083 mm. The American specimens, however, average slightly larger than those reported by Etheridge, but apparently there is no consistent difference in size between Mississippian and Pennsylvanian representatives of the species.

Holothurian spicules which might possibly be confused with *P. traquairii* have not yet been reported from either the Mesozoic or Cenozoic sediments. On the other hand, some spicules of the modern *Caudina arenta* Gould and *Laetmophasma fecundum* Ludwig, among others, rather closely resemble these Paleozoic forms.

Collection. All specimens of this species illustrated on Plate 20 are in the collection of Walker Museum of Paleontology, University of Chicago.

PROTOCAUDINA KANSASENSIS (Hanna)
Plate 20, figures 2, 6
Laetmophasma kansasensis HANNA, (part) *1930*, Jour. Pal., vol. 4, p. 413, pl. 40, figs. 1, 2, 4–7.

For convenience in classification I suggest that ultimately Hanna's original description of this species be restricted so as to include only those individuals with four central openings and ten outer perforations. This is particularly advisable inasmuch as such spicules are obviously the most common of this general Kansas type, and probably will be found to be wide-spread in Pennsylvanian strata. Such a restriction would at present, however, leave some of Hanna's specimens (other than those which obviously belong to *P. traquairii*) without a name, and, therefore, until further material is available for study, I am including under *P. kansasensis* all of the forms which he thus designated except those with eight outer perforations.

The measurements of a typical Brownwood shale (Texas) representative of this species are as follows:

Diameter of disc.....0.2417 mm.
Greatest width of inner holes....0.0458 mm.

EXPLANATION OF PLATE 20

FIGS. 1, 3–5, 7–11, 14–17, 22–24, 26, 28—*Protocaudina traquairii* (Etheridge). 1, Glen Dean specimen, ×100; 3–5, Glen Dean specimens, ×50; 7–11, Glen Dean specimens, ×25; 14, Glen Dean specimen, ×25; 15–16, Paint Creek specimens, ×25; 17, Glen Dean specimen, ×50; 22–23, Paint Creek specimens, ×25; 24, Glen Dean specimen, ×28; 26, Glen Dean specimen, ×75; 28, Paint Creek specimen, ×50.

2, 6—*Protocaudina kansasensis* (Hanna). 2, Keechi Creek specimen, ×75; 6, the same, ×25.

25, 27—*Protocaudina hannai* Croneis, n. sp. 25, Paint Creek specimen, ×25; 27, the same, ×75.

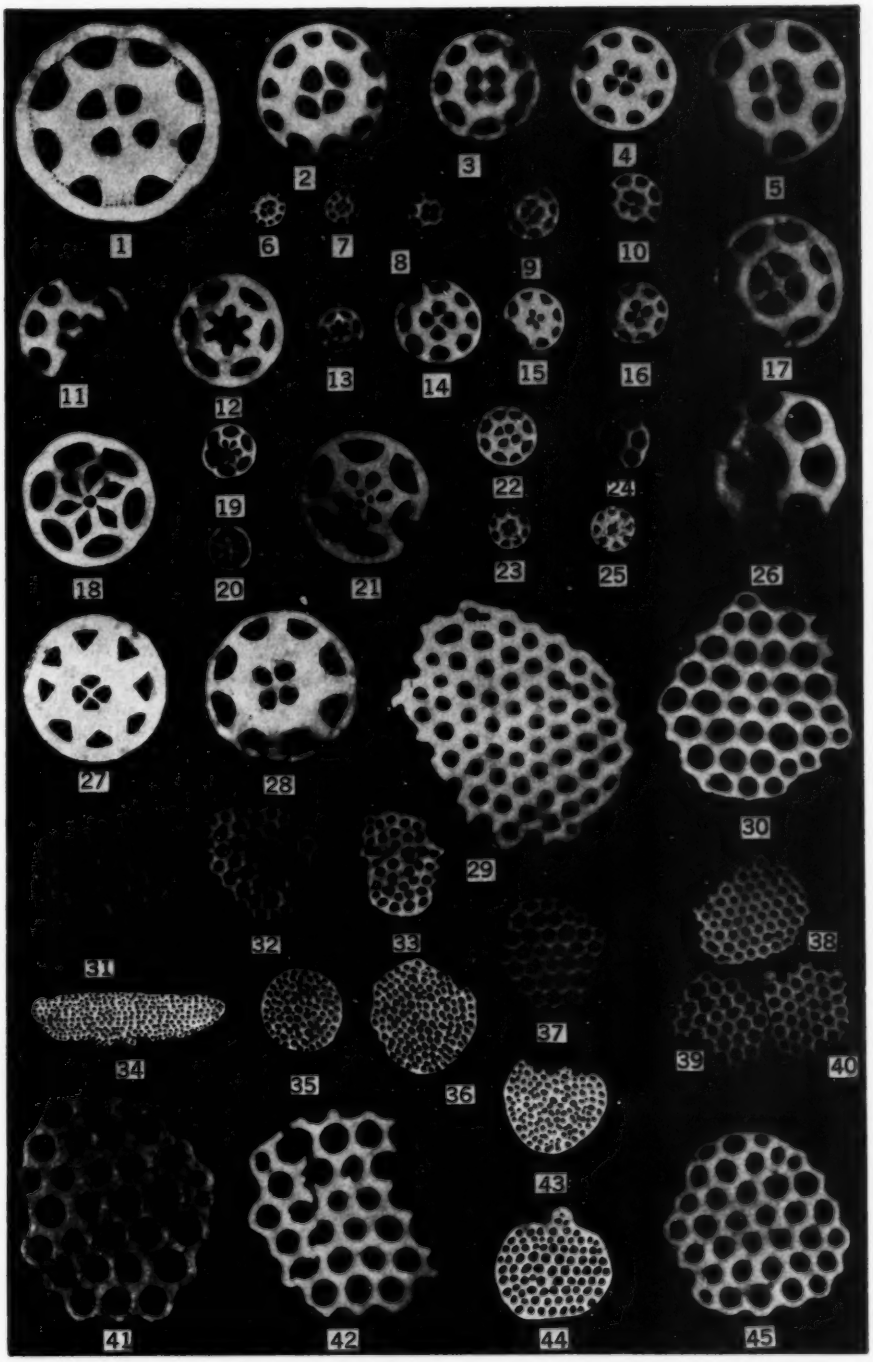
12, 13—*Paleochiridota waylandensis* Croneis, n. sp. 12, the type, ×50; a smaller specimen, ×25.

18, 19—*Paleochiridota plummerae* Croneis, n. sp. 18, Keechi Creek specimen, ×50; 19, a specimen of somewhat different proportions, ×25.

20—*Paleochiridota radiata* Croneis, n. sp. The type, ×20.

21—*Paleochiridota terquemi* Croneis, n. sp. The type, ×60.

29–45—*Ancistrum?* several species. 29, 30, Millsap formation near Millsap, Texas, ×60; 31–33, Keechi Creek shale near Mineral Wells, Texas, ×25; 34–36, Paint Creek formation, Prairie du Longe Creek, St. Clair County, Illinois, ×25; 37, Keechi Creek shale, near Mineral Wells, Texas, ×25; 38–40, Millsap formation near Millsap, Texas, ×25; 41, 42, same locality, ×50; 43, 44, Paint Creek, same locality as number 34, ×25; 45, Keechi Creek shale near Mineral Wells, Texas, ×50.



Croneis and McCormack—Fossil Holothuroidea

Greatest height of inner holes...0.0333 mm.
Greatest width of outer holes...0.0395 mm.
Greatest height of outer holes...0.0316 mm.
Width of rim.....0.0220 mm.

A larger specimen for the Keechi Creek shale (Texas) has a diameter of 0.3167 mm., and a rim thickness of 0.0333 mm.

The species has not as yet been reported from Mississippian horizons.

Occurrence. Elmdale shale, Elmdale, Kansas; Burlingame limestone, Burlingame, Kansas; Chase formation near Cottonwood Falls, Kansas; Brownwood shale of Graford formation, 1 mile east of Wiles, Texas; Keechi Creek shale of Mineral Wells formation, shale below Palo Pinto limestone scarp, 7.4 miles by road north of Crazy Hotel, Mineral Wells, Texas.

Collections. Kansas specimens in University of Kansas collection; Texas specimens in Walker Museum of Paleontology, University of Chicago.

PROTOCAUDINA HANNAI Croneis, n. sp.
Plate 20, figures 25, 27

Concavo-convex, nearly circular discs with a central portion rising above a rim to which it is connected by eight short spokes, which are slightly irregular (ornamented?) along their outer edges. The eight perforations between spokes are triangular in shape. The markings of the central area comprise four circular impressions which fail to perforate the spicule completely. The central area is large for this genus.

The rim is somewhat irregular on its outer circumference, but not definitely scalloped. Its inner margin is spineless. The measurements of the type specimen are as follows:

Diameter of disc.....0.2667 mm.
Width of rim.....0.03 mm.
Average width of openings along rim.....0.035 mm.

Remarks. This species may be distinguished from its congeners by its large central area without complete perforations, and by its triangular outer openings. Owing to imperfect preservation and minuteness of markings the exact character of the central ornamentation is open to some question. In any case the markings are not complete perforations (as might be judged from the figures).

Some of the individuals of this species are somewhat more delicate than the type and are characterized by slightly wider outer perforations.

The specific name is in honor of G. Dallas Hanna.

Occurrence. Paint Creek formation of Chester series, 1/3 mile southwest of McCuen School, near center Section 2, T. 5 S., R 9 N., Randolph County, Illinois; Paint Creek formation, north bank of Prairie du Longe Creek, NE corner, NW 1/4 Section 10, T. 2 S., R 9 W., St. Clair County, Illinois; also from "Lower Okaw" locality unknown, sample labeled "Sect. of River, Old No." Illinois Geological Survey.

Collection. Walker Museum of Paleontology, University of Chicago.

Genus PALEOCHIRIDOTA Croneis, n. gen.

Calcareous, concavo-convex fossil holothurian discs with six outer spokes, and a variety of ornamental perforations or markings in the central area. Rim circular or scalloped. Genotype *Paleochiridota plummerae.*

Remarks. The small spines of the

inner circumference of the rim, mentioned under specific descriptions, probably will turn out to be a generic feature, but one whose use will be somewhat limited by the fact that perfect preservation is required to be certain of their presence. The genus to date is known to occur in North America only in the Pennsylvanian of Texas, but some European Mesozoic and Cenozoic spicules, described under a variety of names, probably belong here.

PALEOCHIRIDOTA PLUMMERAE Croneis, n. sp.
Plate 20, figures 18–19

Prominently concavo-convex discs with an elevated central portion rising above a rim to which it is connected by six spokes. The six openings between spokes are elongate suboval in outline; the seven perforations of the central area comprise a single small rounded central hole, and six larger, hastate openings, each so situated as to lie on the inward continuation of the radius of a spoke.

The rim is slightly scalloped, inasmuch as it narrows at the points of spoke junction. On the concave side the rim seems to be continuous since the spokes are attached on the convex side only. There is also a row of about six very minute inward-directed spines on the inner edge of the rim at each of the six outer perforations. The measurements of two well preserved specimens are:

Remarks. From these figures and from the illustrations it may be seen that the perforations of the central area have somewhat different proportions in these two individuals. This is thought to represent individual variation, but when more material is obtained it may prove to be of specific importance. The species is readily distinguished from its congeners by its central perforation pattern.

This beautiful spicule has been named in honor of Mrs. Helen Jeanne Plummer who collected it.

Occurrence. Keechi Creek shale member of Mineral Wells formation; road ditch 2.5 miles by road WNW of Salesville, Texas, on Graford road.

Collection. Walker Museum of Paleontology, University of Chicago.

PALEOCHIRIDOTA RADIATA Croneis, n. sp.
Plate 20, figure 20

Prominently concavo-convex discs with an elevated central portion rising above a rim to which it is connected by six spokes. The six openings between spokes are vaguely semicircular in outline. The central area is not perforated but is marked on the convex side by six slight grooves each of which radiates from the center of the mid-area down the middle of a spoke to its junction with the rim. On the concave side the marking is similar except that ridges take the place of the grooves.

Measurements of Paleochiridota plummerae

	Specimen A	*Specimen B*
Diameter of disc	0.2833 mm.	0.3167 mm.
Diameter of central hole	0.0208 mm.	0.0180 mm.
Average long dimension of six surrounding holes	0.0322 mm.	0.0443 mm.
Average short dimension of the same	0.0250 mm.	0.0277 mm.
Average long dimension of six outer openings	0.0586 mm.	0.0667 mm.
Average short dimension of the same	0.0333 mm.	0.0417 mm.

The rim is very slightly scalloped along its outer edge, and its inner margin reveals five (possibly six) minute spines at each of the perforations. The measurements of the type are as follows:

	mm.
Diameter of disc	.2833
Average greatest height of perforations	.0417
Average greatest width of perforations along rim	.067
Width of rim	.033

Occurrence. Keechi Creek shale, Mineral Wells formation, shale below Palo Pinto limestone escarpment, 7.4 miles by road north of Crazy Hotel, Mineral Wells, Texas.

Collection. Walker Museum of Paleontology, University of Chicago.

PALEOCHIRIDOTA TERQUEMI Croneis, n. sp.
Plate 20, figure 21

Prominently concavo-convex discs with an elevated central portion rising above a rim to which it is connected by six spokes. The six openings between the spokes are elongate suboval in outline. The central area is marked by six sub-hastate perforations each of which lies on the inward continuation of the radius of a spoke, and by three small, rounded central openings.

The rim is only very slightly scalloped by constrictions at points of spoke junction. The small spines of the rim apparently are much as in other members of the genus, but they are too poorly preserved in the type to be counted.

Remarks. In size this species is essentially identical with *P. plummerae.* The three small central openings, however, will serve to distinguish *P. terguemi* from this close relative. Moreover, the six larger central perforations are apparently more rounded than in *P. plummerae.*

Occurrence. Keechi Creek shale, Mineral Wells formation, shale below Palo Pinto limestone scarp, 7.4 miles by road north of Crazy Hotel, Mineral Wells, Texas.

Collection. Walker Museum of Paleontology, University of Chicago.

PALEOCHIRIDOTA WAYLANDENSIS
Croneis, n. sp.
Plate 20, figures 12–13

Prominently concavo-convex discs with an elevated central portion rising above a rim to which it is connected by six spokes. The six openings between spokes are elongate suboval in outline. On the convex side the central area is marked by a six-rayed star-like impression which fails to perforate the spicule completely. Each bluntly terminated ray of this central marking lies along the inward continuation of the radius of a spoke. On the concave side the central area appears solid.

The rim is scalloped to a very slight degree owing to vague constrictions at the points of junction of the spokes. It is also marked by a row of about five very minute, inward-directed spines on its inner edge at each of the six outer perforations.

The measurements of the type are as follows:

	mm.
Diameter of disc	0.3
Average long dimension of outer holes (along rim)	0.0612
Average short dimension of outer holes	0.0326
Inner point to inner point across center marking	0.05

Outer point to outer point across center marking.....0.125

Remarks. *P. waylandensis* closely resembles *P. plummerae* in many important features, but the markings of the central area differ radically; and, although this point is not ascertained beyond all doubt, the spines of the rim may be slightly more numerous in the latter species than in the former.

Occurrence. Wayland shale of the Graham formation, four miles west of Eastland, Texas, north of old road and Bankhead highway.

Collection. Walker Museum of Paleontology, University of Chicago.

Genus ANCISTRUM Etheridge, 1881

Plate 20, figures 29–45;
plate 21, figures 2–8, 17–22, 29, 39, 54

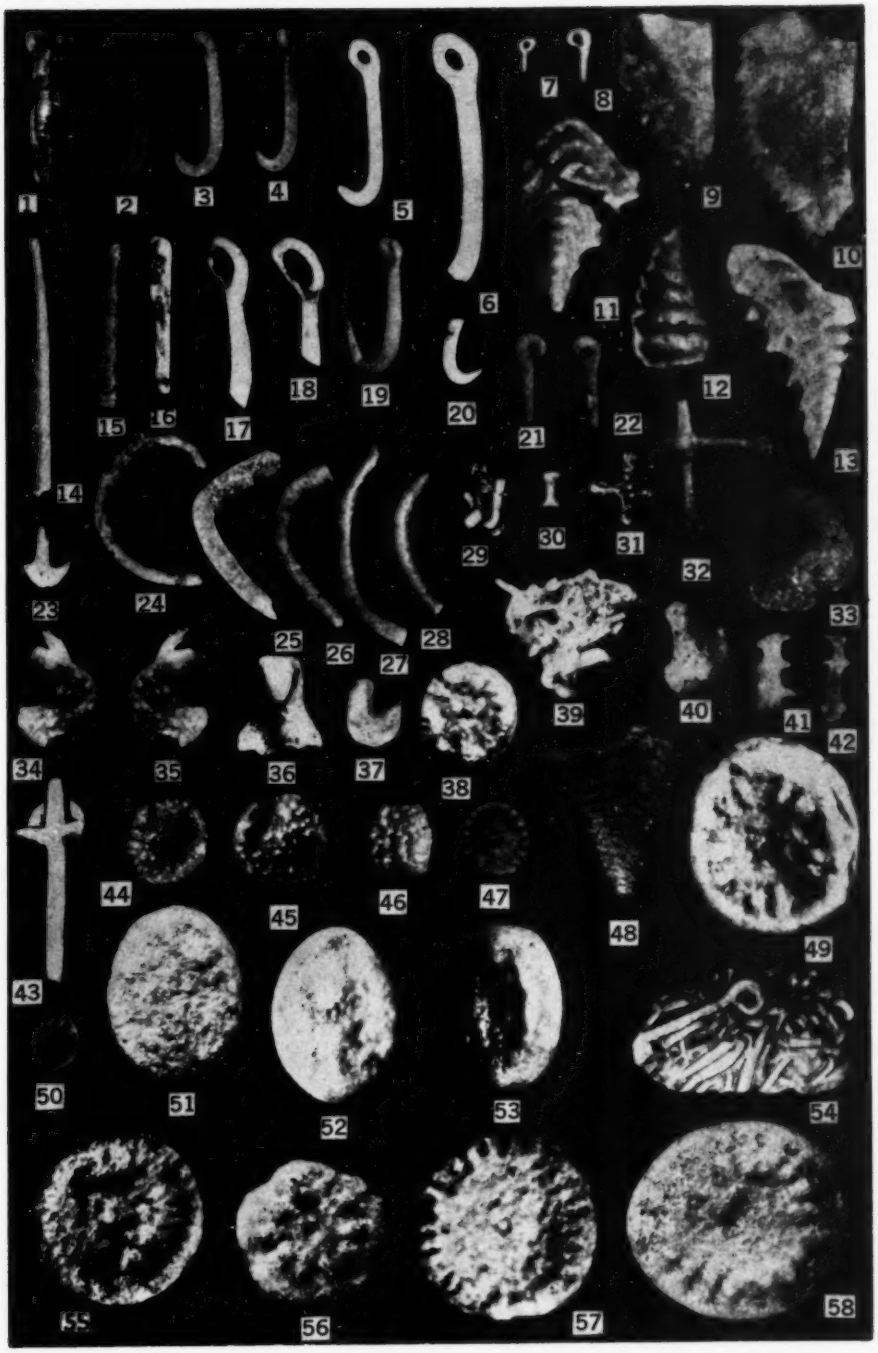
Etheridge's description: Plates of integument irregularly oval in form; perforations variable in number and size; articular process for anchor absent. Anchor spicules in the form of a one-fluked plain (?) hook. Size of plates varying from 1/40th to 1/50th of an inch; size of perforations from 1/200th to 1/250th inch.

Remarks. Etheridge's genus is one which later should be restricted to include only the fishhook-like spicules which really merit the Greek designation. For the present, however, the plate material at hand does not warrant detailed generic or specific differentiations, and therefore, there is included on Plate 20 the figures of a number of perforated discs which future study undoubtedly will show may well be classed as a number of different species of several different genera.

The specimens from the Pennsylvanian of Texas (figures 29–33, 37–42, 45), although differing considerably among themselves, nevertheless have a very different aspect from those of the Chester of Illinois (figures 34–36, 43–44), which have a denser structure and finer perforations. These latter plates, although found elsewhere in the upper Mississippian sequence, are to date most common and characteristic of the Paint Creek sediments. A typical

EXPLANATION OF PLATE 21

FIGS. 1—Tack-like body from Brownwood shale, Bridgeport, Texas, ×25.
2, 17, 18, 54—*Ancistrum ludwigi* Croneis, n. sp. All from Brownwood shale, Bridgeport, Texas, ×25.
3–8, 19–22, 29, 39—*Ancistrum brownwoodensis* Croneis, n. sp. All from Brownwood shale, Bridgeport, Texas; 6, ×50, others ×25.
9–13, 48—Holothurian fronds. 9–11, 13, 48, Shetlerville-Renault section, Hardin County, Illinois, ×25; 12, Glen Dean formation, near Vienna, Illinois, ×25.
14–16—Supporting rods? Paint Creek formation, St. Clair County, Illinois, ×25.
23, 30, 40–43—Miscellaneous echinoderm remains. 23, 40–43, indeterminate spicules from Paint Creek formation, St. Clair County, Illinois, ×25; 30, holothurian spire from Keechi Creek shale near Mineral Wells, Texas, ×25.
24–28—"C"-shaped bodies. 24, Glen Dean formation near Vienna, Illinois, ×25; 25–28, Paint Creek formation, St. Clair County, Illinois, ×25.
31–32—Tetraradiate bodies. 31, Clore formation near "Philadelphia school" Hardin County, Illinois, ×25; 32, Keechi Creek shale near Mineral Wells, Texas, ×25.
33—*Etheridgella porosa* Croneis, n. sp. Wayland shale near Eastland, Texas, ×25.
34–37—Unidentified hooks. Shetlerville-Renault section, near Union School, Hardin County, Illinois, ×25.
44–47, 49–53, 55–58—Imperforate discs and buttons. All from the Shetlerville and Renault formations in Hardin County, Illinois, ×25.



Croneis and McCormack—Fossil Holothuroidea

specimen from this formation measures 0.3167×0.350 mm., and has perforations ranging in diameter from 0.0175 to 0.0333 mm. In the Pennsylvanian of Texas they thus far appear to be most numerous in the Millsap formation and the Keechi Creek shale. A specimen from the latter horizon measures 0.3833×0.5333 mm., and is marked by perforations ranging from 0.043 to 0.053 mm. in diameter.

These plates, in many instances, not only resemble those described by Etheridge from the Carboniferous of Scotland and by Schlumberger from the Eocene of Chaussy, but they are also very similar to a great variety of modern holothurian spicules. In fact, although some refinements of classification are possible with this type of deposit, it is of the sort which gives least promise of stratigraphic importance.

The fishhook-like spicules illustrated on Plate 21 are in this country confined to the Pennsylvanian of Texas, where they are most characteristic of the Brownwood shale, and to the Pennsylvanian Boggy and Francis formations of the Ada, Oklahoma district where they recently have been discovered by Mr. R. V. Hollingsworth of the University of Oklahoma. In Europe most of the specimens have been taken from one locality, Woodend quarry, near Fordel, Fife, but Issler has found a few individuals in the Liassic rocks of Schwabia.

ANCISTRUM BROWNWOODENSIS Croneis, n. sp.
Plate 21, figures 3–8, 19–22, 29, 39

Fishhook-like spicules with the eye rim slightly inclined toward the point of the hook. The width of the nearly circular eye opening is considerably less than the diameter of the haft. Haft essentially straight for the greatest part of its length, and rounding rather abruptly into the hook. The dimensions of three complete specimens are:

Measurements of Ancistrum brownwoodensis

Figure	*3*	*4*	*18*
	mm.	mm.	mm.
Length	0.849	0.812	0.7833
Greatest diameter of haft	0.091	0.012	0.1083
Greatest length of point	0.105	0.067	0.310
Width of hooked portion	0.3167	0.2167	0.304
Inside diameter of eye	0.078	0.065	0.058
Diameter of eye rim	0.183	0.1667	0.155

Remarks. This species is distinguished from others of the genus by means of its small eye opening. It resembles *A. nicholsoni* Etheridge in many respects, but not only is the eye relatively larger in that species, but the eye rim lies in the same plane as the haft.

A. brownwoodensis is the most characteristic and abundant holothurian remain thus far found in the Pennsylvanian of Texas.

Occurrence. Brownwood shale of Graford formation, Bridgeport, Texas, claypit.

Collection. Walker Museum of Paleontology, University of Chicago.

ANCISTRUM LUDWIGI Croneis, n. sp.
Plate 21, figures 2, 17, 18, 54

Fishhook-like spicules with the eye rim moderately inclined toward the point of the hook. The width of oval eye opening is about as great as the diameter of the shaft; and the length of the opening is generally slightly less than twice its width. The measurements of one complete and two fragmentary specimens are as follows:

Occurrence. Brownwood shale, Graford formation, Bridgeport, Texas, claypit.

Collection. Walker Museum of Paleontology, University of Chicago.

Measurements of Ancistrum ludwigi

Figure	2	17	19
	mm.	mm.	mm.
Total length	0.954	0.967	0.683
Outside width of eye	0.170	0.250	0.250
Inside width of eye	0.068	0.142	0.142
Inside length of eye	0.116	0.217	0.240
Width of shaft	0.065	0.158	0.140

Remarks. This species is distinguished from its congeners by the large size of its eye opening. It is similar to the specimens Issler illustrated from the Liassic of Schwabia under the designation "holothurian remains" (which, for convenience, are here named *Ancistrum issleri* Croneis, n. sp.), particularly in the inclination of the eye rim; but the Jurassic specimens of this genus differ from all the Carboniferous representatives in the angular junction their hook makes with the shaft.

A. ludwigi is not represented in our collections by a specimen which has a complete hook, but there is every reason to suppose that this feature is developed in many of the individuals which may later be referred to this species. Plate 21, figure 54, gives an idea of the masses of these spicules which in some cases may be washed from the enclosing sediments.

Genus ETHERIDGELLA Croneis, n. gen.

Concavo-convex irregularly rounded to nearly circular discs which rise on the convex side to a low, rounded, central spire. Surface marked by very fine irregular depressions, but by no complete perforations. Genotype, *Etheridgella porosa.*

ETHERIDGELLA POROSA Croneis, n. sp.
Plate 21, figure 33.

Concavo-convex irregularly rounded discs whose convex surface rises gently to a small, low, central prominence or spire. The surface is marked by very fine irregular (polygonal?) depressions which are not complete perforations.

The concave side is not markedly impressed and thus the plates have considerable thickness in their central portion. The markings of the concave side are similar to those of the other, but perhaps have a greater tendency toward rounded outlines. The overall measurements of the type are 0.6333×0.7 mm., the central spire has a minimum diameter of 0.1 mm., and the surface markings vary in diameter from 0.010 to 0.0167 mm.

Remarks. This is a very distinctive spicule not likely to be confused with any previously described form.

Occurrence. Wayland shale of Graham formation, 4 miles west of Eastland, Texas, north of old road and Bankhead highway.

Collection. Walker Museum of Paleontology, University of Chicago.

INCERTAE SEDIS

Grouped under this heading is a large number of spicules, probably of holothurians, some of which merely await additional material for generic and specific descriptions, as well as a number of calcareous bodies some of which may represent the remains of other classes of animals.

Imperforate discs or buttons. Imperforate, oval to circular calcareous bodies of considerable thickness are relatively common in the Chester of Illinois, being abundant in the Shetlerville-Renault sequence and occurring also in the lower Okaw and Clore. The variety of these bodies is fairly well illustrated by Plate 21, figures 38, 44–47, 49–53, and 55–58. Some of these are unquestionably holothurian spicules, for instance, figures 45, 46, 51, and 55, but some may belong to other classes of the echinoderma. The obvious disposition of these remains as pelmatozoan columnals meets difficulty in that none is perforated (though a few have a central depression) and that the average diameter is considerably less than 1 mm.

Tetraradiate bodies. Two definitely tetraradiate holothurian bodies are in our collection. Plate 21, figure 32, represents a specimen from the Keechi Creek shale of the Mineral Wells formation near Mineral Wells, Texas. The longer complete rod has a length of 0.5667 mm. and is semi-eyed at its termination; the shorter complete rod is 0.51 mm. long, and is grooved at its end. This is a form somewhat similar to that described by Etheridge from the lower Carboniferous of Fordel, Fife, and illustrated in Plate 18, figure 38, this paper.

Plate 21, figure 31, shows a cross from the Clore (Chester) formation near the "Philadelphia School" Hardin County, Illinois. This spicule has vague surface markings at the center and the ends of the rods are slightly clubbed. The overall greatest dimension of the specimen is 0.4166 mm., and the rods have a length of about 0.16 mm.

These spicules show a close relationship to deposits seen in the modern holothurian family Psychropodidae. More especially they simulate tetraradiate bodies from the intestinal wall of the modern genus *Euphronides*, as may be seen by comparing the Carboniferous spicules with Plate 16, figure 12.

"C"-shaped bodies. These are very common in the Chester sediments of Illinois, but are most abundant in the Paint Creek and Clore formations. Typical representatives of these unornamented rods with various degrees of curvature are shown in Plate 21, figures 24–28. The greatest dimension of this type of spicule varies from about 0.8 to 1.2 mm.

Supporting rods. "Supporting rods"

are common in the Chester of Illinois, but to even a greater extent than in the case of the "C"-shaped bodies, one cannot be certain that these rods are not deposits of creatures other than holothurians. Most of the specimens considered to belong here have an average length of about 0.75 mm.

Fronds. Several types of holothurian fronds occur in the Chester sediments of Illinois, where they have been found in the Glen Dean, Renault, and Shetlerville formations. The variety in these deposits is illustrated by Plate 21, figures 9–13, and 48. Further work and additional material are needed for accurate generic and specific descriptions, but these bodies give some evidence of being stratigraphically important. Some of the fronds, however, resemble those in the body of the modern *Cucumaria frondosa* (Linnaeus), and several of the Illinois specimens are similar to those from the lower Carboniferous of Fordel, Scotland.

Miscellaneous. Under this heading are grouped a variety of diverse calcareous particles, mostly from the Chester of Illinois, which are of problematical origin. Plate 21, figure 1, however, illustrates a tack-shaped body from the Brownwood shale of Texas, which probably was formed in the integument of a holothurian. Plate 21, figure 30, represents a Chester holothurian spire, and Plate 21, figures 23, and 40–43, illustrate possible Chester holothurian remains of wide diversity. Plate 21, figures 34–37, represent hooks of undetermined, but probably echinodermal, origin which nevertheless are common enough in the Shetlerville-Renault section to be of stratigraphic value as horizon markers.

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SOME OSTRACODES FROM THE SALEM LIMESTONE, MISSISSIPPIAN, OF INDIANA

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ABSTRACT

This paper describes forty-six species of ostracodes (forty-three new) from the Salem limestone of Indiana. The species are assigned to seventeen genera, including three new, as follows: *Oliganisus* (Kloedenellidae), *Savagella* (Kirkbyidae), and *Microcheilus* (Bairdiidae). A number of suggestions are made with regard to the orientation of ostracodes, and the new species and genera are described in accordance with these suggestions.

INTRODUCTION

The Salem formation, in its typical occurrences in Indiana, is a massive, richly fossiliferous, and sparsely oolitic limestone which occupies a narrow zone extending southeast from Quincy, Indiana, to the Ohio River. Its thickness ranges from about 2 to 100 feet. The great abundance of the shells of *Endothyra baileyi* (Hall) has given rise to the impression that the formation is strongly oolitic, but actual oolites are rare and are restricted to a few narrow, irregular zones. A large percent of the fossils, however, have a thin, soft coat of calcium carbonate, undoubtedly acquired during deposition. Many outcrops and quarry faces are appreciably cross-bedded. This fact, coupled with the worn character of many of the shells and their strikingly diminutive size, has suggested the theory that the formation is a shallow water, probably lagoonal, deposit.

It has been suggested that the Salem limestone may not actually be a distinct formation, but rather a near-shore phase of either the Warsaw or the St. Louis. At present there seems to be no definite proof of either of these suggestions. The railroad cut at Spergen Hill, Norris, Indiana, shows the Salem limestone unconformably on the Harrodsburg limestone (Warsaw), and at other outcrops it is capped by the Mitchell limestone (St. Louis and younger). According to classification by Ulrich, the Warsaw, Salem and St. Louis formations comprise the Meramec group, which lies between the Osage group below and the Ste. Genevieve limestone above.

Silicified Salem fossils are found abundantly in many places in the red clays resulting from the weathering of the limestone. Elsewhere the rapid disintegration of the stone has yielded calcareous sands almost en-

tirely composed of the shells of minute organisms. The best specimens are obtained however, when thin surface-weathered slabs are crushed, and the fragments are examined under a binocular microscope. The writer's collection includes about 30,000 well-preserved ostracodes obtained in this way.

An effort to determine the presence of faunal zones in the Salem formation was entirely negative in results.

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CARAPACE ORIENTATION

The vexatious problem of the orientation of fossil ostracodes, always a puzzle in the description of new forms, has recently received careful consideration from J. H. Bonnema[1] and E. Kummerow.[2] It is inherent in the problem, perhaps, that these competent men, using the same groups of ostracodes for illustration, seeking analogies in modern forms and supplementing knowledge with reason, have been able in many cases to arrive at different results. Bonnema and Kummerow have restricted their attention to the highly lobed members of the Beyrichiacea. This paper treats with a few of the simpler ostracodes that they did not mention.

The Salem formation of Indiana is peculiar as regards the average small size of its fossils. Many of the shells of brachiopods, gastropods, and pelecypods, that are normally megascopic, are microscopic in the Salem. It is interesting to note, however, that the true microscopic forms, including ostracodes and foraminifera, are not reduced in size but average rather larger than similar forms in other parts of the Carboniferous. Many of the ostracodes tend toward greater obesity than the average species of their respective genera. This fact, coupled with the position of greatest obesity, makes the Salem ostracodes of some value in throwing light on proper orientation.

Among the genera in question are *Sansabella* Roundy, *Glyptopleura* Girty, and *Jonesina* Ulrich and Bassler. Each of these genera has typically an oblong-rhomboidal carapace, and as commonly oriented, the left valve is the larger, the position of maxi-

[1] *Jour. Pal.*, vol. 4, no. 2, p. 109, 1930.
[2] *Jour. Pal.*, vol. 5, no. 2, p. 155, 1931.

mum thickness is anterior, and the obtuse cardinal angulation introduces a retral swing. *Sansabella inflata* Geis, n. sp. (pl. 22, figs. 2a, b) is typical of this shape. In this species one end is strongly inflated, and the position of greatest convexity is just inside the ventral angle of the end that is commonly regarded as "anterior!" *Oliganisus punctatus* Geis, n. sp. (pl. 22, figs. 3a, b), *Savagella lindahli* (Ulrich) (pl. 22, figs. 8a, b), *Glyptopleura karli* Geis, n. sp. (pl. 22, figs. 12a, b), and *Jonesina oblonga* Geis, n. sp. (pl. 23, figs. 6a, d) are close analogies.

If these figures are compared with modern ostracodes several striking discrepancies appear.

(1) Modern ostracodes that are strongly inflated at one end and comparatively thin at the other, show that the inflated end is the posterior. The Recent species, *Cytherura clavata* H. B. Brady (pl. 22, figs. 1a-c), *Xestoleberis foveolata* H. B. Brady (pl. 22, figs. 7a-c), and *Cytherella cribrosa* H. B. Brady (pl. 22, figs. 4a-c), are typical. If one considers that ostracodes are free swimming, a posterior position of maximum thickness is not surprising. It may be regarded almost as axiomatic that any free-swimming organism, within the limits imposed by its essential anatomy and subject to variation due to such phenomena as reproductive and feeding habits and method of locomotion, tends to fashion its exterior to facilitate movement. It is quite apparent that *Sansabella inflata* and *Savagella lindahli* must have been strongly handicapped in locomotion, if they were actually oriented as we are accustomed to consider them.

(2) Such modern ostracodes as possess or approach the oblong-rhomboidal outline of shell under consideration have the obtuse dorsal angulation at the *anterior* and the ventral truncation (in so far as that is a feature of such shells) at the *posterior* end. *Cythere demissa* H. B. Brady (pl. 22, figs. 6a,b), *Loxoconcha australis* H. S. Brady (pl. 22, figs. 5a-c), *Cythere flos-cardui* H. B. Brady (pl. 22, figs. 10a-b), and *Cytherella venusta* H. B. Brady (pl. 22, figs. 13a-c), are but a very few of the Recent examples that illustrate these features. If one looks at the plates in any comprehensive treatment of modern ostracodes, similar illustrations will be seen to abound. It is interesting to note that in orienting fossil species of *Cytherella*, paleontologists are careful to harmonize them with modern forms, but in dealing with genera that are not represented in modern faunas, the precedent so set is often ignored.

Again, if a large number of specimens of the Salem species mentioned above are studied carefully, it will be noted that there is a considerable range in the comparative thickness of the ends. The end containing the "retral" swing is more or less stable, but the ventrally truncated end may vary from comparatively thin to strongly obese. If one bears in mind that the head, antennae, and mandibles are stable features of the animal's anatomy at one stage of growth but that the posterior of a female is inflated at times while the male may

normally be content with a smaller shell capacity, then it becomes apparent that the end of the shell most subject to variation in thickness is probably the *posterior*, particularly if that end holds even normally the maximum convexity.

The species *Glyptopleura parvacostata* Geis, n. sp. (pl. 22, figs. 9a-d) illustrates the features described. This is a fairly common species found at all levels of the Salem limestone, at all the outcrops from which the writer has collected, and the two forms, the thin and the inflated, are always found together. There is little difference between them except the degree and position of maximum convexity. Now, if the ventrally truncated end is regarded as anterior, one is at a loss for a plausible explanation of this strong difference between the several variations of the one species. If the truncated end is regarded as posterior, then it becomes at once apparent that the inflated shells might have belonged to fertile females, whereas the compressed shells were carried by males.

Oliganisus sulcatus Geis, n. sp. (pl. 23, figs. 5a, b), is another interesting species. A deep furrow closely parallels the contact margin of the inflated end, reminiscent of similarly placed furrows in some species of *Healdia*. In *Healdia* these furrows are unquestionably *posterior*, but if the conventional orientation of *Jonesina* and *Glyptopleura* is to be retained in this new genus, then the closely analogous furrows in *Oliganisus sulcatus* are anterior features, which seems very unlikely.

If the arguments given above are sound, then their logical inferences, that the obtuse cardinal angulation in oblong forms containing it marks the anterior, and that a strongly inflated end is likely to be posterior, may be of value in orienting other

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EXPLANATION OF PLATE 22

FIGS. 1*a–c*—*Cytherura clavata* H. B. Brady, *a*, left view; *b*, dorsal view; *c*, front view. Recent. ×40.

2*a*, *b*—*Sansabella inflata* Geis, n. sp., *a*, left view; *b*, dorsal view. Salem. ×22.

3*a*, *b*—*Oliganisus punctatus* Geis, n. sp., *a*, left view; *b*, dorsal view. Salem. ×22.

4*a–c*—*Cytherella cribrosa* H. B. Brady, *a*, left view; *b*, dorsal view; *c*, front view. Recent. ×50.

5*a–c*—*Loxoconcha australis* H. B. Brady, *a*, left view; *b*, dorsal view; *c*, front view. Recent. ×40.

6*a*, *b*—*Cythere demissa* H. B. Brady, *a*, left view; *b*, dorsal view. Recent. ×65.

7*a–c*—*Xestoleberis foveolata* H. B. Brady, *a*, left view; *b*, dorsal view; *c*, front view; female. Recent. ×50.

8*a*, *b*—*Savagella lindahli* (Ulrich), *a*, right view; *b*, dorsal view; inflated form, probably female. Salem. ×12.

9*a–d*—*Glyptopleura parvacostata* Geis, n. sp., *a*, left view; *b*, dorsal view; female; *c*, left view; *d*, dorsal view, male, ×22.

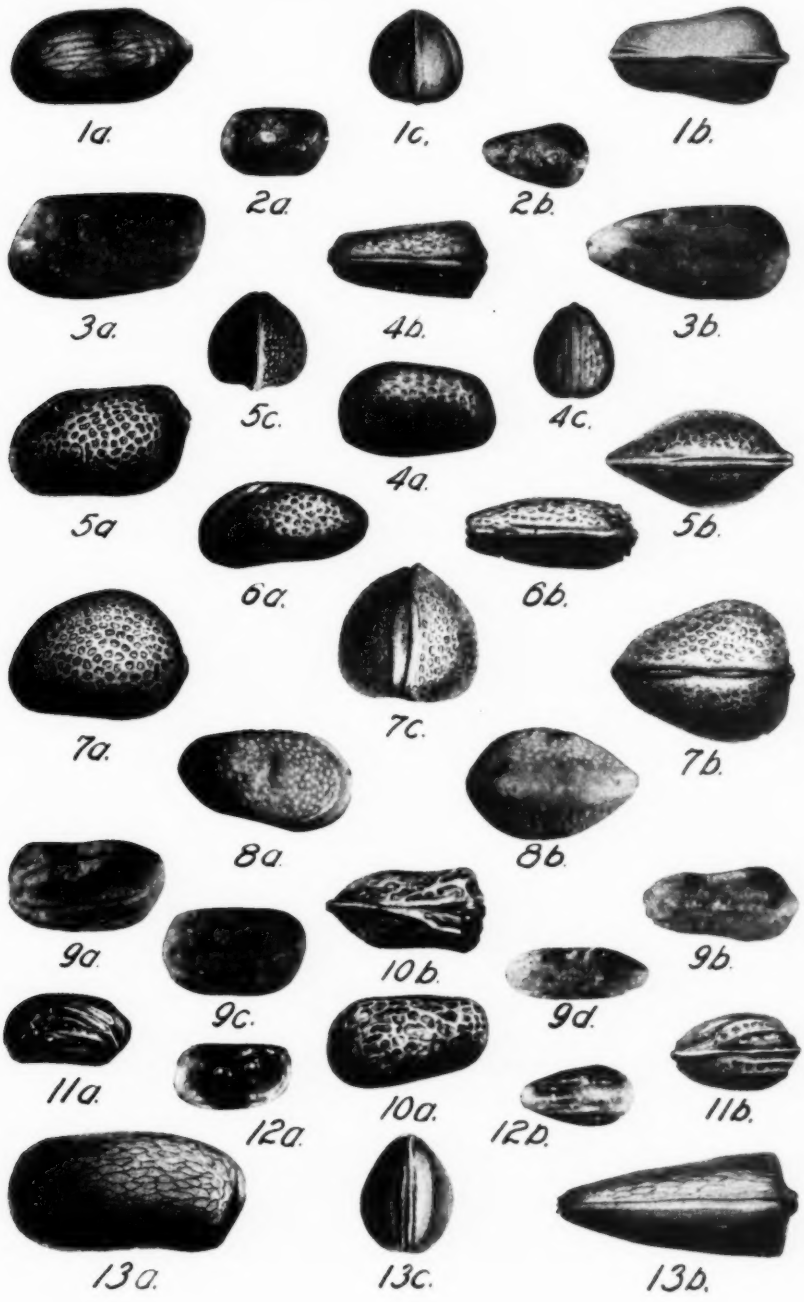
10*a*, *b*—*Cythere flos-cardui* H. B. Brady, *a*, left view; *b*, dorsal view. Recent. ×50.

11*a*, *b*—*Cytherura curvistriata* H. B. Brady, *a*, left view; *b*, dorsal view. Recent ×50.

12*a*, *b*—*Glyptopleura karli* Geis, n. sp., *a*, left view; *b*, dorsal view. Salem. ×22.

13*a–c*—*Cytherella venusta* H. B. Brady, *a*, left view; *b*, dorsal view; *c*, front view. Recent. ×50.

(All illustrations of modern species were taken from H. B. Brady's "Report on Ostracoda," *Rept. Voy. H.M.S. Challenger*," *Zool.*, vol. 1, 1880.)



Geis—Salem (Mississipian) Ostracodes

forms, such as genera of the families Kloedenellidae, Kirkbyidae, Primitiidae, and Glyptopleuridae.

The Primitiidae are particularly instructive in this connection. Ulrich and Bassler[3] illustrate representative species of the genera of this family. It will be noted that, in so far as the species possess an oblong-rhomboidal outline, they are oriented with the obtuse cardinal angulation as a posterior feature, giving rise to a retral swing. There are two significant exceptions, *Primitiopsis planiformis* Jones, nos. 7 to 9, and *Dicranella bicornis* Ulrich, no. 15. These species have the posterior end clearly indicated by unusual features, the first by a posterior compartment or brood pouch, the second by a broad frill-like border, *and in each case the "retral swing" is anterior.*

The author recognizes one apparent weakness in the arguments above presented. The members of the family Leperditiidae are universally recognized as having a definite backward swing. It is possible, however, that such orientation is based on the belief that the dorsal nodes mark the position of the lateral eyes. Such interpretation is at best uncertain. It is difficult to see how this only partially thinned spot in the thick shells of the Leperditiidae could have functioned very efficiently to permit the infiltration of light. Again, when the lateral eyes are present in modern ostracodes, they are paired. Accept ing the principle that "the present is the key to the past," we would normally expect the nodes to be paired on all Leperditiidae that possess them, as well as in such other genera, as *Paraparchites*, which possess like prominences, if they indeed mark the position of lateral eyes. That, however, by no means holds true. In addition to the species in which the dorsal nodes are not present or are present on only a few specimens, there are a number of species that have the node on *one valve only*. The apparent objection suggested by the orientation of the Leperditiidae is not necessarily valid then, because their orientation is also uncertain.

Two other genera demand special attention in this paper, *Kirkbya* Jones, and *Amphissites* Girty. *Kirkbya* was originally described as having the right valve the larger, an orientation that throws the greater thickness and the dorsal "shoulder," in such species as have unequal ends and only one shoulder, to the posterior. Roth[4] changes the orientation of the genus for the following reasons.

(1) The more acute angle is taken as the one on the anterior extremity; and with this *arbitrary arrangement* (italics Geis), the backward swing is away from the more acute angle, and is toward the more obtuse angle. This backward swing is a very strong point in the orientation of most ostracoda.

(2) The thickest portion of the carapace is usually chosen as the posterior, which is apparently the rule used by Jones in the orientation of his specimens of (*Kirkbya*) *permiana*. Yet it will be noted that in *permiana* the thickest portion is just under the dorsal margin, rather than along the ventral margin. When the rule is used it will usually be found that the thickest portion is on the posterior

[3] Ulrich, E. O., and Bassler, R. S., Paleozoic Ostracoda: *Md. Geol. Survey*, Silurian, p. 298, fig. 15, 1923.

[4] Roth, Robert, A Revision of the Ostracod Genus *Kirkbya* and Subgenus *Amphissites: Wagner Free Inst. Sci.*, vol. 1, p. 23, 1929.

ventral margin and that most of the brood pouches are placed in that region. As a result it is *thought best to negative this rule* (italics Geis) in dealing with *Kirkbya permiana* and also with the genus *Kirkbya* and subgenus *Amphissites.*

(3) The left valve has a groove, outside of which there is a flange along the free margin. The right valve has a single flange, which fits into this groove.

Roth's first argument, as an "arbitrary arrangement," is invalid in a discussion of orientation. Further, it has already been shown that the obtuse cardinal angle, in such modern forms as have only one such angle, is an anterior device, and that the "backward swing" is in reality a forward swing, an arrangement which, by analogy, supported by other independent arguments, may be in the greater number of cases safely supplied to fossil ostracodes.

The second argument is a negative one: since it happens in *Kirkbya* that the position of greatest convexity is dorsal rather than ventral, the rule of posterior position of greatest convexity does not apply; hence the position of greatest convexity is assumed as anterior. This conclusion is based on doubtful logic. More important, however, is the fact that when modern female ostracodes carry their eggs and broods, they are always carried in the rear, *and often in the postero-dorsal part.* Blake[5] states that "in all the recent types possessing such a chamber (a definite brood chamber) it is postero-dorsal in position. " It does not stretch probability, therefore, to conclude that the inflated dorsal shoulder in certain species of *Kirkbya* may have been utilized as a brood chamber, and hence is probably posterior. *Kirkbya dorsoconvexa* Geis, n. sp. (pl. 23, figs. 9a, b) distinctly presents such a possibility. The fact that some species of *Kirkbya* are uniformly convex does not invalidate that conclusion.

Roth's third argument, that the left valve is the larger, so completely depends on the determination of the anterior and posterior ends that it can have no standing.

There seems no sound reason, then for questioning the orientation given *Kirkbya* by Jones, and there are several strong ones indicating that it was correct. The writer believes that it should be retained.

The genus *Amphissites* Girty was described under the erroneous impression that it was completely equivalved. In Girty's description, however, the type species, *A. rugosus*, was oriented with the anterior end the thicker, and the triangular area at the dorsal end of the fourth ridge near the anterior end of the hinge. Roth, in the paper quoted above, retains this orientation, apparently because it conforms with his revision of the genus *Kirkbya*. As a consequence *Amphissites*, as well as *Kirkbya*, is regarded by him as having the left valve narrowly overlapping the right.

The usual objections to placing the thicker end to the anterior are, of course, applicable. According to Roth, such species as *A. minuta* Roth, in which one of the dorso-

[5] Blake, C. H., The Ostracode Genus Hollinella: *Jour. Pal.*, vol. 4, no. 3, p. 298, 1930.

lateral nodes is obsolete, while the other is strongly developed and the end containing it is blunt, the blunt end is the anterior and constitutes the "cutting edge." This seems unnatural. A similar difficulty is presented by *A. vanniae* Geis, n. sp. If a longitudinal section be cut through the middle node parallel to the greatest length of shell, the outline of the carapace is seen to be as indicated in Figure 1. One end is much blunter than the other, and the middle node rises very gently on one side but falls abruptly on the other. If the animal moved to the left (in the orientation of the figure), the subacute end and long slope of the node must have offered materially smaller resistance than if movement was in the direction of the blunt end and the abrupt slope of the node. The subacute end must, further, have been a much better receptacle for the antennae and mandibles than for the abdomen and brood.

On the basis of the arguments here presented, the author has oriented the species described in this paper in accordance with the suggestions stated above, that is, *Jonesina*, *Sansabella*, *Glyptopleura*, *Kirkbya*, and *Amphissites* are all oriented with the right valve the larger, and the strongest convexity (in so far as the ends differ) posterior. The new genera are described according to the same orientation. *Paraparchites* doubtless should also have been reoriented, but pending more complete data it was considered best to leave it temporarily undisturbed.

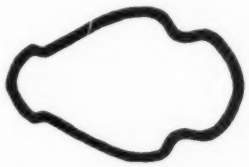


FIG. 1. Cross-section of the carapace of *Amphissites vanniae* Geis, n. sp., parallel to the greatest length of the shell.

The types will be retained by the Geology Department, University of Illinois. Their catalogue numbers are cited after the descriptions.

SYSTEMATIC DESCRIPTIONS

Family APARCHITIDAE Ulrich and Bassler

Genus PARAPARCHITES Ulrich and Bassler, 1906

PARAPARCHITES SUBCIRCULARIS Geis, n. sp.
Plate 23, figures 1*a–d*

Carapace obese, subcircular in side view, posterior end broadly rounded, anterior very slightly truncated ventrally; ventral margin strongly, and dorsal gently convex. Highest at or slightly behind the median line, thickest just in front of the center. Valves unequal, the right valve the larger and strongly peripheral ventrally in left view, progressively less so toward the cardinal angles; the left valve arches above the right at the dorsal contact; actual overlap negligible. Carapace ovate in dorsal view, posterior end gently compressed. An "eye" tubercle is frequently present on young shells just below and behind the antero-cardinal angle of the left valve, but in larger shells it is usually obsolete. There is

characteristically a thickening of the left valve along its dorsal margin, which is sometimes flattened, often producing a low broad node near the hinge line one-third of its length from its posterior extremity. Hinge-line straight, carapace smooth, valves thick. An obscure rounded muscle scar is observable in well-preserved casts.

Average measurements of six large specimens: length 2.0 mm.; height 1.55 mm.; thickness 1.103 mm. Average measurements of six smaller specimens: length 1.49 mm.; height 1.157 mm.; thickness .84 mm.

P. subcircularis is closely related to *P. nicklesi* Ulrich, but is larger than Ulrich reports his species. It is shorter in relation to its height, and has an arched dorsal margin of the left valve instead of a straight margin, angulated at its extremities, as Ulrich pictures *P. nicklesi*. Again, the "eye" spine of Ulrich's type figure is much more prominent than in the Salem species.

Girty reports *P. nicklesi* from the Moorefield shale of Arkansas. The forms he figures are much longer than *P. subcircularis*, though they agree in having the "eye" node only on the left valve, if it is present at all.

Hall seems to have confused the shells here identified as *P. subcircularis* with *P. carbonarius* (Hall). Of the twenty-four specimens he identified as *P. carbonarius* and presented to the American Museum of Natural History, fourteen are *P. subcircularis*.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Walsh and P. M. B. Quarries, Bedford, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana. Abundant at each of these localities.

Types. Holotype, no. M 300; paratypes, no. M 301.

PARAPARCHITES CARBONARIUS (Hall)
Plate 23, figures 2*a*, *b*

Cythere[6] *carbonaria* HALL, *1856*, Trans. Albany Inst., vol. 4, p. 33.

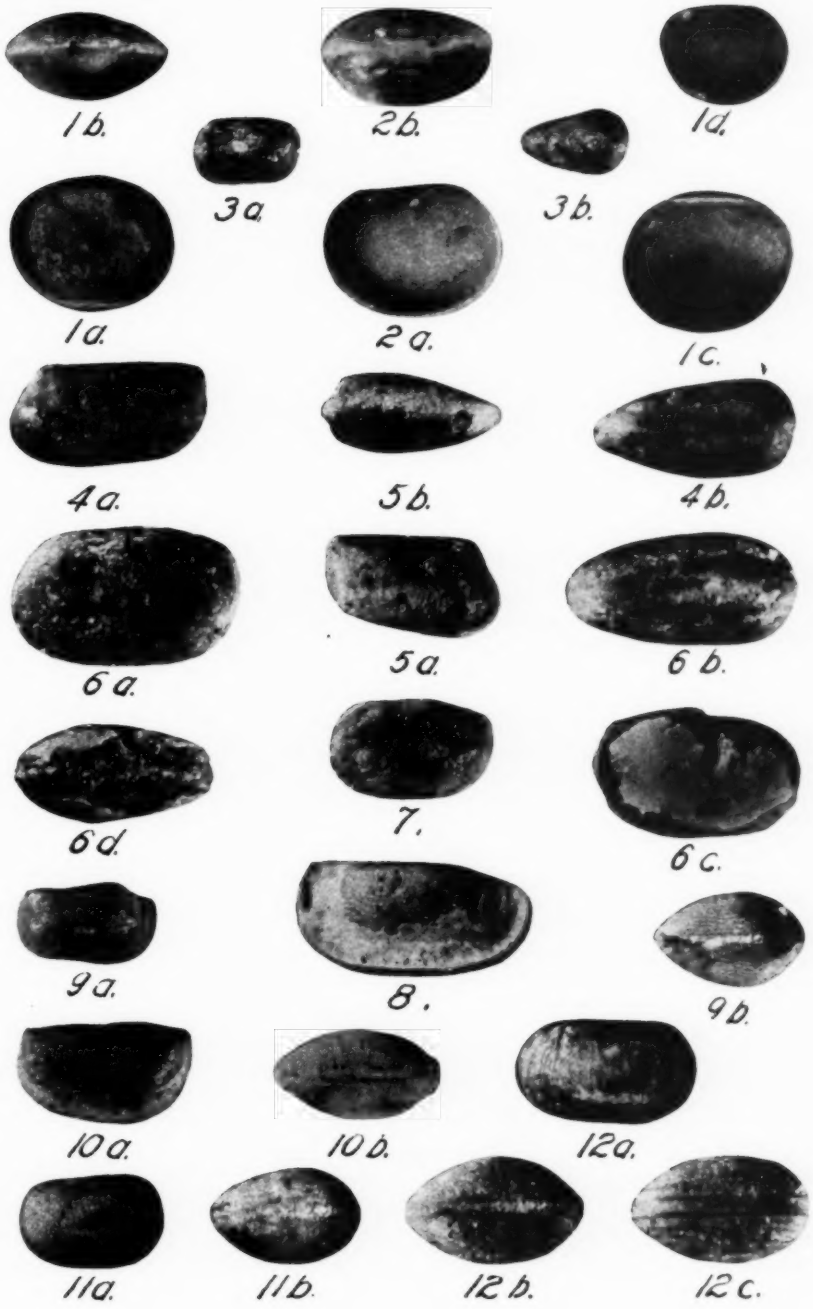
Leperditia carbonaria WHITFIELD, *1882*, Am. Mus. Nat. Hist., Bull., vol. 1, p. 94, pl. 9, figs. 24–27.—HALL, *1882*, Ind. Dept. Geol. and Nat. Res., 12th Ann. Rept., p. 375, pl. 32, figs. 24–27.—CUMMINGS AND BEEDE, *1905*, Ind. Dept. Geol. and Nat. Res., 30th. Ann. Rept., (figures only), pl. 26, figs. 24–27.

It is not possible to determine beyond a doubt what form Hall had in

[6] Misprint for *Cytherina*.

EXPLANATION OF PLATE 23

FIGS. 1*a–d*—*Paraparchites subcircularis* Geis, n. sp., *a*, left view; *b*, dorsal view; *c*, right view; *d*, left view of smaller specimen showing "eye" tubercle. ×12.
2*a*, *b*—*Paraparchites carbonarius* (Hall), *a*, left view; *b*, dorsal view. ×12.
3*a*, *b*—*Sansabella inflata* Geis, n. sp., *a*, left view; *b*, dorsal view. ×22.
4*a*, *b*—*Oliganisus punctatus* Geis, n. sp., *a*, left view; *b*, dorsal view. ×22.
5*a*, *b*—*Oliganisus sulcatus* Geis, n. sp., *a*, right view; *b*, dorsal view. ×22.
6*a–d*—*Jonesina oblonga* Geis, n. sp., *a*, left view; *b*, dorsal view; *c*, right view; *d*, dorsal view of cast. ×22.
7—*Jonesina sinuodorsata* Geis, n. sp., left view. ×22.
8—*Kirkbya welleri* Geis, n. sp., left view. ×22.
9*a*, *b*—*Kirkbya dorsoconvexa* Geis, n. sp., *a*, left view; *b*, dorsal view. ×22.
10*a*, *b*—*Kirkbya rothi* Geis, n. sp., *a*, left view; *b*, dorsal view. ×22.
11*a*, *b*—*Amphissites rotundus* Geis, n. sp., *a*, left view; *b*, dorsal view. ×22.
12*a–c*—*Amphissites mimicus* Geis, n. sp., *a*, left view; *b*, dorsal view; *c*, ventral view. ×22.



Geis—Salem (Mississippian) Ostracodes

mind in describing this species. Of the twenty-four specimens of Hall's original collection, now in the American Museum, more than half are the form described in this paper as *Paraparchites subcircularis*. When Whitfield figured and redescribed the Salem species in 1882, he seems to have selected the less abundant form as typical. Since his figures and comments are rather clear, his selection is accepted. Hall's original description, and Whitfield's comments are quoted below:

> Shell oval or subovate, gibbous; slightly compressed towards the margins; ventral[7] margin straight, one-third less than the greatest length of the valves; extremities rounded, broader anteriorly,[8] dorsal margin forming a broad curve; surface smooth.
>
> This species does not exceed a single line in length. Compare with *C. pusilla* McCoy.—(Hall).
>
> The carapace of this species is broadly ovate, slightly narrowed anteriorly; hinge line straight about half as long as the valves, which are compressed towards the dorsal line and become rapidly inflated toward the ventral; extremities of the hinge angular, so as to produce a slight feature at this point. Right valve considerably larger than the left, and overlapping it except on the dorsal margin, at which point the left projects above the right. Ocular spot not definitely determined. There is a small tubercle present on some individuals just behind or at the middle of the length, on the right valve, indicated on the figure, but which is very obscure and rarely seen. On the casts at this point a circular scar is also visible on each side, indicating the position of the muscular tubercle, but no evidence of the ocular tubercle has been observed.—(Whitfield.)

The "ocular" tubercle has been observed by the author on more than half of the specimens of a large collection. It is situated just below and behind the antero-cardinal angle on the left valve. The internal muscle scar is a large irregular node, bordered postero-ventrally by a short, sharp ridge and postero-dorsally by a shallow, broad pit. Valves thick.

Measurements of four typical specimens average: length 2.45 mm.; height 1.68 mm.; thickness 1.2 mm.

Localities. P. carbonarius is present at all horizons and localities where collections were made, but is less abundant than *P. subcircularis*.

Types. Plesiotypes, no. M 302.

Superfamily BEYRICHIACEA
Family KLOEDENELLIDAE
Ulrich and Bassler

Genus JONESINA Ulrich and Bassler, 1909

The genus *Jonesina*, described originally as having the left valve the larger, is here considered, for reasons enumerated in the first part of this paper, as having the right valve the larger.

JONESINA OBLONGA Geis, n. sp.
Plate 23, figures 6*a–d*

Carapace strong, oblong-rhomboidal in side view, dorsal and ventral margins straight, posterior end obliquely rounded, truncated ventrally, anterior end broadly rounded ventrally, flattened dorsally, joining the hinge at an obtuse angle. Dorsal view elongate or subcuneate, anterior sharply rounded, posterior blunt. Valves subequal, the right narrowly overlapping the left, most noticeably at the cardinal angles. Carapace compressed toward the antero-superior

[7] Ventral and dorsal margins confused.
[8] Anterior and posterior margins confused.

angle, inflated toward the postero-inferior margin. Maximum height median, maximum thickness inside the ventro-posterior angle. A broad shallow sulcus lies in the dorsal half about one-third the shell-length from the anterior, expressed internally by a strong ridge which is nodose at its lower end. Hinge equals about three-fourths the total shell-length, and is impressed at the posterior end; exact nature of contact unknown. Surface smooth, valves thick.

Length 1.44 mm.; height 0.94 mm.; thickness 0.83 mm.

J. oblonga is readily distinguished from *J. ampla* Warthin by the scarcely perceptible ventral and lateral overlap of the former species. It differs from *J. craterigera* (Jones and Kirkby) by its smooth surface and shallower sinus, and from *J. arcuata* (Bean) in the position of greatest convexity and lack of the submarginal ridges.

Locality. Railroad cut at Spergen Hill, Norris, Indiana; rare.

Types. Holotype, no. M 303; paratype, no. M 304.

JONESINA SINUODORSATA Geis, n. sp.
Plate 23, figure 7

Carapace oblong-rhomboidal in side view, dorsal margin slightly sinuous, ventral margin flatly convex, anterior end flattened dorsally, posterior ventrally truncated. Ends subacute in dorsal view, posterior abruptly, anterior gently compressed. Maximum height median or anterior, maximum thickness at the posterior third near the ventral margin. Valves unequal, the right narrowly overlapping at the cardinal extremities and along the free margin. A narrow sulcus lies in the dorsal half slightly in front of the middle, and a very shallow short sulcus occupies the antero-dorsal margin laterally compressed and sharp. Hinge short, equalling approximately five-eights of the shell length, somewhat anteriorly situated, and only slightly impressed at its posterior end; exact nature of the hinge contact uncertain. Surface smooth, valves thin.

Length 1.24 mm.; height 0.83 mm.; thickness 0.62 mm.

J. sinuodorsata is much less obese than *J. oblonga*, and is constricted inside the posterior margin where *J. oblonga* is inflated. The constricted posterior portion, the inconspicuous sulci, and the less strongly impressed hinge distinguish *J. sinuodorsata* from *J. texana* Harlton and *J. vinitaensis* Harlton.

Locality. Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no M 305; paratype, no. M 306.

Genus OLIGANISUS Geis, n. gen.

Carapace oblong-rhomboidal in side view, dorsal and ventral margins straight, posterior end angulated dorsally, truncated ventrally, anterior end well rounded ventrally and flattened dorsally, forming a quite obtuse angle with the dorsum. Dorsal view cuneate or subcuneate, posterior blunt, anterior rather sharp. Maximum height anterior, maximum thickness posterior, carapace laterally compressed toward the antero-cardinal angle. Valves subequal, the

right very narrowly overlapping the left at the cardinal angles and free margins. Surface punctate, and otherwise ornamented by a pit above and in front of the center, by one or two very shallow sulci under the anterior end of the hinge, and by a sulcus or furrow paralleling the posterior contact margin. Hinge long, straight, slightly impressed toward the posterior; dorsal contact margins apparently plain.

The name is derived from the Greek, *oligos*-small, and *anisos*-unequal.

Genotype: *Oliganisus sulcatus* Geis, n. sp.

Range: Mississippian.

This genus is distinguished from *Jonesina* by its punctate surface, its nearly equal valves, its subcentral pit, and its posterior marginal furrows. It differs from *Primitia* in its less strongly developed sulci, the surface ornamentation, and in the posterior furrows. The laterally constricted and sharp antero-cardinal angle is characteristic of *Oliganisus*.

OLIGANISUS PUNCTATUS Geis, n. sp.
Plate 23, figures 4*a*, *b*

Carapace oblong-rhomboidal in side view, dorsal and ventral margins straight; anterior end well rounded ventrally, straight dorsally, forming quite an obtuse angle with the dorsum; posterior end flatly curved, slightly truncated ventrally. Dorsal view cuneate, anterior subacute, posterior broad and blunt. Maximum height at the antero-cardinal extremity, maximum thickness below the center of the posterior fourth; carapace compressed toward the antero-superior angle. Valves subequal, the right very slightly overlapping the left at the cardinal extremities and along the free margins. A dorsally elongated pit lies above and in front of the center, and a broad shallow sulcus connects the pit and the dorsum. A short narrow sulcus or furrow parallels the middle of the posterior margin. Hinge straight, almost equal to the greatest length of shell, and slightly impressed. Surface irregularly punctate, the punctae widely separated; valves thick.

Length 1.28 mm.; height 0.7 mm.; thickness 0.7 mm.

Locality. Railroad cut at Spergen Hill, Norris, Indiana; rare.

Types. Holotype, no. M 307; paratype, no. M 308.

OLIGANISUS SULCATUS Geis, n. sp.
Plate 23, figures 5*a*, *b*

Carapace oblong-rhomboidal in side view, dorsal and ventral margins straight, posterior flatly curved and slightly truncated ventrally, anterior broadly rounded ventrally, straight dorsally, forming an obtuse cardinal angulation. Dorsal view subcuneate, anterior subacute, posterior abruptly constricted and acute or subacute. Maximum height at the antero-cardinal angle, maximum thickness slightly below and behind the center; carapace compressed toward the antero-superior angle. Valves subequal, the right valve very narrowly overlapping at the free edges and the cardinal angles. A dorsally elongate pit lies above and in

front of the center, at the lower end of a broad shallow sulcus. In front of the pit an ill defined node separates it from a second much smaller sulcus. A broad, deep furrow or sulcus closely parallels the entire posterior contact. Hinge straight, almost equal to the entire length of shell, and not impressed in the dorsum. Surface dotted with irregularly and thinly scattered punctae; valves thick.

Length 1.03 mm.; height 0.63 mm.; thickness 0.55 mm.

O. sulcatus differs from *O. punctatus* in bearing an anterior shallow sulcus and in the strong development of the posterior furrow; in *O. punctatus* the position of greatest thickness is higher and farther back. Otherwise the two are similar.

Locality. Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no. M 309; paratype, no. M 310.

Family KIRKBYIDAE

Ulrich and Bassler

Genus KIRKBYA Jones, 1869

Jones described *Kirkbya* as having the right valve the larger. Roth, however, in 1929, concluded that such orientation is incorrect, and some authors, both before and since his publication, have oriented new species with the left valve the larger. The writer has presented considerations supporting the validity of Jones' earlier conception, and the Salem species are here described in harmony with Jones' work.

KIRKBYA DORSOCONVEXA Geis, n. sp.
Plate 23, figures 9*a*, *b*

Carapace in side view oblong-quadrate, dorsum straight except as interrupted by the posterior shoulder, ventral margin gently sinuate, ends rounded broadly up to about the dorsal fourth, then curving in more strongly to the obtuse cardinal angles. Carapace ovate in dorsal view, anterior end sharply rounded and less inflated than the blunt posterior. Maximum height at the posterior third, maximum thickness in the dorsal half, one-third the shell length from the posterior. Valves subequal, the right narrowly overlapping the left along the free margins. A shallow sulcus or furrow falls from the dorsal margin just inside the postero-cardinal angle, approximately parallel to and well inside the margin, and ends at the elongate subcentral pit. Just above and in front of the furrow is a strong shoulder which rises above the hinge contact posteriorly and gradually dies away anteriorly. A low sharp keel closely parallels the free margin, separated by two rows of fine reticulations from a very weak ridge, which in turn is separated by two rows of fine reticulations from a third stronger keel. Surface otherwise finely reticulate, the reticulations in rows which tend to parallel the margins. Hinge almost equalling the greatest length of carapace, straight, impressed below the shoulder, and ornamented by a flange and two lateral teeth in the right valve, articulating with a furrow and two sockets in the left.

Measurements of six specimens

average: length 0.96 mm.; height 0.52 mm.; thickness 0.56 mm.

K. dorsoconvexa differs from *K. perplexa* Roth in having finer reticulations and only one node or shoulder.

Locality. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; common.

Types. Holotype, no. M 311; paratype, no. M 312.

KIRKBYA ROTHI Geis, n. sp.
Plate 23, figures 10*a*, *b*

Carapace subovate, dorsal margin straight except as it is slightly interrupted by the obscure posterior shoulder; ventral margin straight and inclined upward anteriorly; anterior end flattened dorsally and meeting the cardinal extremity at slightly more than ninety degrees, posterior end flatly curved, forming an angle of slightly less than ninety degrees with the dorsum. Dorsal view ovate, anterior end slightly sharper than posterior. Carapace highest at the posterior one-third, thickest just above and behind the center. Valves subequal, the right narrowly overlapping the left along the free margins. A very obscure shoulder rises slightly above the hinge-line at the posterior one-fourth, and fades into the general convexity anteriorly. An elliptical pit lies just in front of the center of the carapace. There are three or four false keels, the first at the free margin, low and sometimes imperceptible, the second is strong and sharp, separated from the first by a narrow unornamented furrow; the third weaker, sometimes obscure, separated from the second by two or three rows of fine reticulations ventrally, and joining the second at the cardinal angles. Surface otherwise finely reticulate, with no special arrangement of pits and lines. Hinge equalling the greatest length of carapace, gently impressed; exact nature of dentition uncertain.

Measurements of four specimens average: length 1.12 mm.; height 0.721 mm.; thickness 0.717 mm.

K. rothi resembles *K. permiana* var. *varica* Roth, but differs in bearing only one shoulder or node and in the upward deflection of the venter. It is also more obese.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana. This species is not common, though well distributed vertically in the Salem.

Types. Holotype, no. M 313; paratype, no. M 314.

KIRKBYA WELLERI Geis, n. sp.
Plate 23, figure 8

Carapace in side view oblong-subtrapezoidal, dorsal margin straight except as slightly deflected by the posterior shoulder, ventral margin flat, and inclined upward posteriorly; posterior end obliquely rounded, anterior broadly curved ventrally, flattened dorsally, joining the hinge-line at an angle slightly greater than ninety degrees. Carapace highest at about the anterior third, thickest dorsally at the posterior one-third. Valves subequal, the right very narrowly overlapping the left. A low false keel closely par-

allels the contact margin, separated by a wide, shallow, apparently unornamented furrow from an exaggerated second keel, whose distal edge is directed downward and outward; as a consequence, the venter is broad and deeply concave. The proximal margin of the inner keel is pierced through by a row of small, vertically elongate holes. Immediately within the inner keel and paralleling it is a deep finely reticulate furrow; beyond the furrow the surface is more coarsely reticulate and is smoothly convex, inflated at the postero-dorsal one-third to form a low shoulder which rises slightly above the hinge. The pit is absent in this species, its position occupied by a small non-reticulate area. Hinge equal to greatest length of shell, straight, impressed; exact nature of hinge ornamentation uncertain.

Length 1.8 mm.; height 0.9 mm.; thickness 0.65 mm.

This species is distinguished from any other species of *Kirkbya* known to the author by the deeply concave venter, and the high inner keel, pierced through at its base by a number of small holes. It is further distinguished from *K. inornata* Roth by its postero-dorsal shoulder and its outline, and from *K. magna* Roth by the absence of the pit.

This species is named for J. M. Weller, who contributed a paratype, now in his possession.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; quite rare.

Types. Holotype, no. M 315; paratypes, no. M 316.

Genus AMPHISSITES Girty, 1910

In his original description of *Amphissites* Girty erroneously considered the genus completely equivalved. The Salem species are described as having the right valve narrowly overlapping the left along the the free margins.

AMPHISSITES ROTUNDUS Geis, n. sp.
Plate 23, figures 11*a*, *b*

Carapace obese, suboblong in side view, dorsal margin straight, ventral flatly convex, ends broadly and evenly curved. Dorsal view ovate, ends rounded. Carapace highest at posterior one-fourth, thickest above and behind the middle. Valves subequal, the right narrowly overlapping the left along the free margins. In this species the middle and posterior nodes of related forms are coalescent, forming a continuous broad low swelling which rises at about one-third the shell-length from the anterior margin in the dorsal half, inclines gently upward, and terminates slightly above the postero cardinal angle; the lower margin of the swelling is marked by a gentle furrow or sulcus which strengthens as it approaches the crescentic subcentral pit. Surface ornamented with fine reticulations, the pits circular in outline on the dorsal swelling and arranged in rows roughly paralleling the dorsal margin; below, the pits tend to be elongate, and are distinctly arranged in rows that parallel the free margins. A narrow keel in each valve parallels the contact margin, ending at the cardinal angles; a sharp low ridge or false keel, sepa-

rated from the marginal keel by a narrow furrow, closely parallels it, and continues along the dorsal contact. Hinge fully three-fourths of total shell-length, depressed in a broad furrow in the dorsum; hinge contact marked by a flange terminated at each cardinal extremity by a simple node in the right valve, a corresponding furrow and two pits are present in the left valve. Valves thick.

Measurements of six typical specimens average: length 0.95 mm.; height 0.62 mm.; thickness 0.64 mm.

A. rotundus is closely related to the Pennsylvanian species *A. geneae* Roth, *A. pinguis* Ulrich and Bassler, and *A. gregeri* Delo. *A. pinguis*, however, has two nodes in place of the coalescent swelling; *A. gregeri* is less inflated, and has only the single marginal keel; and *A. geneae* is thinner, has coarser reticulations, and more or less isolated nodes.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; common.

Types. Holotype, no. M 317; paratypes, no. M 318.

AMPHISSITES VANNIAE Geis, n. sp.

Plate 24, figures 1*a–c*

Carapace obese, suboblong, dorsal margin straight, ventral gently concave, ends smoothly and evenly rounded. Carapace highest at the posterior one-fourth, thickest behind and above the center. Dorsal view ovate, anterior end subacute, posterior sharply rounded, the subcentral node in prominent relief. Valves subequal, the right narrowly overlapping the left along the free margin. A broad transverse swelling or node situated toward the dorsal half of the shell rises at the anterior one-third, strengthens gently to its greatest prominence at the posterior one-third, and is bounded on all sides by a furrow of varying depth. A thin, low ridge encircles the furrow, developing at the dorsum into two weak nodes, the posterior one of which is the stronger. An elongate pit lies in the furrow just below the center of the shell. The free margin is closely bounded by a weak ridge, separated narrowly from a parallel and stronger false keel. A thin ridge branches from the false keel below the antero-cardinal angle, swings out from it laterally and ventrally to the point of greatest divergence well inside the postero-inferior margin, and rejoins the keel at the postero-cardinal angle. Surface otherwise reticulate, the pits irregularly rounded and tending to be arranged in concentric rings on and around the subcentral node, more elongate near the free margins and arranged in lines more or less paralleling the margins. Hinge straight and impressed, equalling three-fourths of the entire carapace in length, the right valve containing a flange and two terminal teeth articulating with a groove and two pits in the left. Valves thick.

Measurements of four specimens average: length 1.12 mm.; height 0.76 mm.; thickness 0.78 mm.

A. vanniae is closely related to the genotype *A. rugosus* Girty but differs in having a lower central node and sharper and lower keels and ridges,

and in the possession of the exactly marginal keel or valve thickening. It differs from *A. weaveri* Roth in having smaller, smoother reticulations, and a less prominent overlap of the right valve at the cardinal extremities.

Localities. Old Cleveland Quarry, Harrodsburg, Indiana; railroad cut at Spergen Hill, Norris, Indiana; and Walsh Quarry, Bedford Indiana; widely distributed but not common.

Types. Holotype, no. M 319; paratypes, no. M 320.

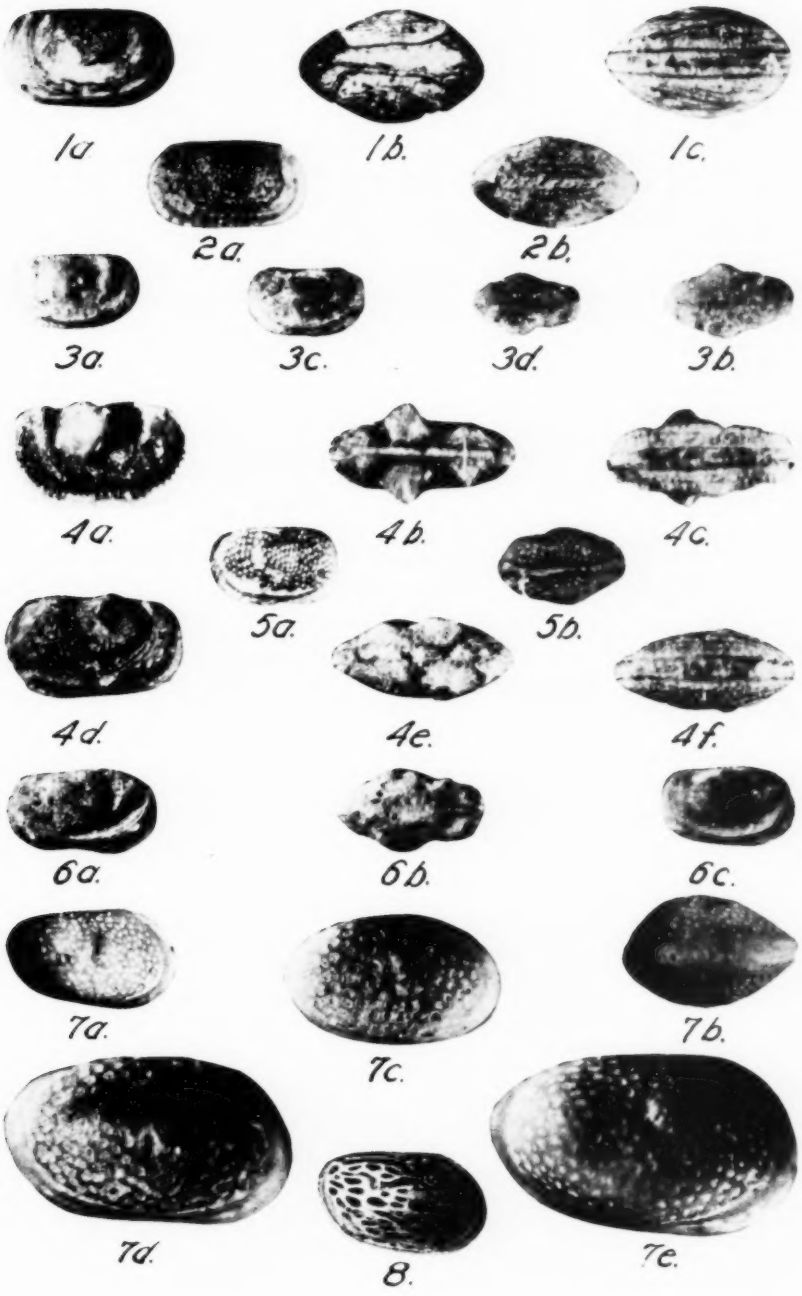
AMPHISSITES MIMICUS Geis, n. sp.
Plate 23, figures 12*a–c*

Carapace obese, suboblong, dorsal margin straight, ventral margin straight or very slightly concave, ends smoothly and evenly rounded. Carapace thickest centrally, highest medially or at the posterior one-fourth. Dorsal view ovate, anterior end subacute, posterior sharply rounded, sides strongly curved. Valves subequal, the right narrowly overlapping the left along the free margins. This species resembles *A. vanniae* in its surface markings, but in each case the markings are much reduced or obsolete. The low swelling in the central third of the dorsal half is undefined, the furrow is clearly present only along its ventral margin, and the encircling ridge is obsolete, its only expression being the very low node near the dorsum in the posterior one-fourth. At the free margins the marginal and submarginal keels are present, but the inner ridge, which in *A. vanniae* separates from the false keel at the cardinal angles and invades the carapace well toward the center at the postero-inferior margin, is either absent altogether or is merely suggested by the arrangement of the reticulations. An elongate pit lies in the furrow below the center. Surface finely reticulate, the dorsal and central reticulations arranged more or less irregularly, more elongate toward the margins, and arranged in rows paralleling the margin. Hinge impressed, straight, equalling three-fourths of the entire carapace in length, the right valve with a flange and two terminal teeth which articulate with a groove and two pits in the left. Valves moderately thick.

Measurements of four specimens

EXPLANATION OF PLATE 24

FIGS. 1*a–c*—*Amphissites vanniae* Geis, n. sp., *a*, left view; *b*, dorsal view; *c*, ventral view. ×22.
2*a*, *b*—*Amphissites planoventralis* Geis, n. sp., *a*, right view; *b*, dorsal view. ×22.
3*a–d*—*Amphissites centronotoides* Geis, n. sp., *a*, left view; *b*, dorsal view, *c*, left view; *d*, dorsal view. ×22.
4*a–f*—*Amphissites altanodosus* Geis, n. sp., *a*, left view; *b*, dorsal view; *c*, ventral view of specimen with full node development; *d*, right view; *e*, dorsal view; *f*, ventral view of specimen showing well preserved surface markings. ×22.
5*a*, *b*—*Amphissites reticulatus* Geis, n. sp., *a*, right view; *b*, dorsal view. ×22.
6*a–c*—*Amphissites nodosulcatus* Geis, n. sp., *a*, left view; *b*, dorsal view; *c*, left view of another specimen. ×22.
7*a–e*—*Savagella lindahli* (Ulrich), *a*, right view; *b*, dorsal view of female, ×12; *c*, *d*, *e*, right views of three individuals showing differences in reticulation. ×22.
8—*Savagella rhomboidalis* (Girty) right view, Girty's type figure of specimen from the Batesville sandstone, Arkansas. ×26.



Geis—Salem (Mississippian) Ostracodes

average: length 1.07 mm.; height 0.66 mm.; thickness 0.72 mm.

A. mimicus resembles *A. vanniae* closely enough that, occurring together as they do, one is inclined to consider one a variation of the other; but a number of specimens closely examined reveal quite consistent differences which warrant their separation.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; fairly rare, but present at practically all levels.

Types. Holotype, no. M 321; paratypes, no. M 322.

AMPHISSITES PLANOVENTRALIS Geis, n. sp.
Plate 24, figures 2*a*, *b*

Carapace inflated, oblong-ovate in side view, dorsal margin straight, ends evenly curved, ventral margin gently sinuate. In dorsal view the posterior end is somewhat sharper than the anterior, and the moderate curvature of the sides is interrupted by a broad subcentral node. Carapace thickest just above the center, and highest at the posterior one-fourth. Valves subequal, the right narrowly overlapping the left along the free margins. Venter flattened. Surface ornamented by a low broad node in the middle of the dorsal half of the shell, with an elliptical pit immediately under it, just below the center of the shell. Two carinate ridges the posterior one the stronger, extend from weak nodes just inside the cardinal angles to more than halfway between the superior and inferior margins, where they tend to curve inward. A weak marginal keel parallels the free margin, narrowly separated from a stronger keel which also borders the hinge contact. A third carina bounds the flattened venter, separated from the second by two rows of fine, rounded reticulations, and is extended up the sides to the cardinal angles where its ends join the second keel. Inside the third carina the reticulations are more or less aligned in rows paralleling the margins, except near and on the subcentral node where they are smaller and irregularly placed. Hinge straight, slightly impressed, about two-thirds the length of the carapace; exact nature of the contact uncertain.

Measurements of four specimens average: length 1.05 mm.; height 0.66 mm.; thickness 0.63 mm.

A. planoventralis differs from *A. rugosus* Girty in having much less prominent markings. The dorsum bears one ridge instead of two, and the anterior end is thicker than the posterior, the reverse of *A. rugosus*. The features are also less prominent than those of *A. centronotus* Ulrich and Bassler, particularly the posterior node.

Localities. Old Cleveland Quarry, Harrodsburg, Indiana; and railroad cut at Spergen Hill, Norris, Indiana; rare and near the top of the Salem in both localities.

Types. Holotype, no. M 323; paratype, no. M 324.

AMPHISSITES CENTRONOTOIDES Geis, n. sp.
Plate 24, figures 3*a–d*

Carapace oblong-quadrate in side view, dorsal margin straight, ventral

margin broadly convex, ends evenly rounded ventrally and slightly flattened dorsally, forming distinct obtuse angles with the cardinal margin. In dorsal view anterior end sharply rounded, posterior blunt, the sides rather flat except as inflated by the prominent subcentral nodes. Maximum height median, maximum thickness above the middle. Valves subequal, the right narrowly overlapping the left along the free margins. A prominent rounded node lies just above the center, and below the node is a small rounded pit. Two elongate and carinate nodes, the posterior one the larger, extend from their position of greatest prominence just inside the cardinal angles to about the ventral one-third, the ends gently inclined inward; a sharp ridge connects the two nodes dorsally. The free margin closely paralleled by a high, sharp false keel. A second sharp ridge joins the first at the cardinal angles, and is separated from it ventrally by two rows of polygonal reticulations. Surface otherwise ornamented with polygonal reticulations of no particular pattern. Hinge straight, almost equalling the greatest length of shell, and impressed; the dorsal contact margin of the right valve contains a flange and two terminal, slightly inferior teeth, which fit into two sockets and a furrow in the left valve.

Two specimens measure: (1) length 1.06 mm.; height 0.7 mm.; thickness 0.65 mm.; (2) length 9.02 mm.; height 0.51 mm.; thickness 0.53 mm.

This species seems closely allied with *A. centronotus* Ulrich and Bassler, but is thinner, with a proportionately more conspicuous subcentral node, especially when the carapace is viewed dorsally or ventrally. A cross-section through the center of *A. centronotus* shows a broad, somewhat flattened venter, but a similar section through *A. centronotoides* shows a rounded venter.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no. M 325; paratypes, no. M 326.

AMPHISSITES ALTANODOSUS Geis, n. sp.

Plate 24, figures 4*a–f*

Carapace oblong-quadrate in side view, dorsal and ventral margins straight; ends rounded ventrally, slightly flattened as they join the cardinal extremities, forming obtuse angles with the dorsum. Greatest thickness of carapace just below the hinge-line and slightly anterior to its middle; maximum height median. Valves subequal, the right narrowly overlapping the left along the free margins. Venter broad, flat. A high vertically carinate node lies just in front of the middle of the dorsal half of the valve, its upper end projecting slightly above the hinge. A moderate sinus bounds the node laterally and ventrally; the sinus in turn is bounded laterally and ventrally by a low, broad, carinate ridge, the cardinal ends of which are elevated to node-like prominence, the posterior node being the larger. A low false keel parallels the contact margin, separated ventrally by three rows of

rounded reticulations from a high, sharp, laterally directed keel, whose distal edge marks the periphery of the flat venter; the two ridges join below the cardinal angles, and a reduced continuation of them parallels the hinge contact. Surface otherwise marked by a subcentral pit, a row of large reticulations at the inside proximal edge of the second false keel, and finer polygonal reticulations roughly arranged to parallel the free margins. Hinge straight impressed, equalling three-fourths of the total shell length; hinge contact composed of a flange and two lateral, slightly inferior teeth in the right valve which articulate with two sockets and a furrow in the left.

Average measurements of three specimens: length 1.13 mm.; height 0.74 mm.; thickness 0.63 mm.

This species is particularly interesting in that, although definitely an *Amphissites* as that genus is now delimited, it possesses strong tendencies toward *Ulrichia*. A careful study of this and closely related forms may in the future contribute an interesting paragraph to our knowledge of the evolution of the two genera.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no. M 327; paratypes, no. M 328.

AMPHISSITES NODOSULCATUS Geis, n. sp.
Plate 24, figures 6*a–c*

Carapace oblong-quadrate in side view, dorsal margin straight except as deflected by the posterior nodes, ventral margin flat; ends flattened dorsally, evenly rounded ventrally, In dorsal view anterior subacute, posterior blunt, the broad subcentral node in prominent relief. Maximum height at about the posterior one-third, maximum thickness in front of and slightly above the center. Valves subequal, the right narrowly overlapping the left at the free margins. Of the three nodes, the more prominent one lies mainly above the center; it is high, broad, rounded ventrally, and invaded dorsally by a narrow sinus, giving the node somewhat the appearance of a fat comma, its end directed posteriorly. Two carinate lateral nodes, the posterior one the stronger, lie just inside the cardinal extremities in the dorsal half of the shell. The marginal false keel is high and sharp, separated ventrally from a second stronger keel by three to four rows of fine reticulations; the two keels join just below the cardinal angles, and their continuation closely parallels the hinge contact. Surface otherwise ornamented by a subcentral pit, and by numerous fine, rounded reticulations arranged in rows which tend to parallel the free margins. Hinge long, straight, gently impressed; exact nature of dorsal contact uncertain.

Measurements of three specimens average: length 0.98 mm.; height 0.6 mm.; thickness 0.58 mm.

A. nodosulcatus closely resembles *A. centronotoides* but has stronger keels and is distinctly separable by the sinus in the subcentral node. The character of the node also distinguishes it from *A. centronotus* Ulrich and Bassler.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Type. Holotype, no. M 329.

AMPHISSITES RETICULATUS Geis, n. sp.
Plate 24, figures 5*a*, *b*

Carapace oblong-ovate in side view, dorsal and ventral margins straight, ends evenly rounded. Dorsal view ovate, posterior bluntly, anterior sharply rounded, sides inflated at the node. Maximum height median, maximum thickness slightly above the middle; venter broad and flat. Valves subequal, the right narrowly overlapping along the free margins. The middle node is small at the base, rounded, relatively prominent; lateral nodes weak. There are three false keels, the marginal one quite subdued and separated from the stronger second keel by a narrow, unornamented furrow. The third keel is separated from the second by three rows of rather coarse reticulations ventrally, where its laterally directed distal edge forms the margin of the flattened venter, and joins the second ridge just below the cardinal angles. Dorsally, one narrow ridge closely parallels the contact margin, another connects the crests of the lateral nodes and closes in to the cardinal angles. Surface otherwise coarsely reticulate. Hinge straight, equalling two-thirds the total shell length, and impressed; exact character of hinge markings uncertain.

Measurements of three specimens average: length 0.89 mm.; height 0.57 mm.; thickness 0.51 mm.

A. reticulatus may be distinguished from *A. pinguis* Ulrich and Bassler by the flattened venter, and from *A. gregeri* Delo by the strong third keel. *A. centronotoides* differs in having a rounded venter and in being more finely reticulate.

Localities. Old Cleveland Quarry, Harrodsburg, Indiana; and Railroad cut at Spergen Hill, Norris, Indiana; rare.

Type. Holotype, no. M 330.

Genus SAVAGELLA Geis, n. gen.

Carapace oblong-rhomboidal in side view, dorsal margin straight, ventral margin gently concave or convex; posterior end truncated ventrally, anterior obtusely angled dorsally. Maximum height anterior, maximum thickness central to posterior. Valves subequal, the left the larger, narrowly overlapping along the free margins and at the cardinal angles. Surface coarsely reticulate except for a wide smooth marginal band. A large pit lies near the center, and there may be a low node anterior to the pit. The left valve bears a flange at the hinge contact which fits into a groove in the right valve.

The genus is named in honor of Prof. T. E. Savage, of the University of Illinois.

Genotype: *Savagella lindahli* (Ulrich)

Range: Mississippian.

The genotype was originally regarded as a *Kirkbya* by Ulrich, and was later referred to *Amphissites* by Roth. The author has indicated that *Amphissites* and *Kirkbya* have the right valve the larger. *Savagella lin-*

dahli differs in having the left valve the larger. The validity of the new genus, however, does not depend on the acceptance of the author's suggestions on orientation of *Amphissites* and *Kirkbya*, since in any event, the overlap of *Savagella* is opposite to that of *Amphissites* and *Kirkbya*. *Savagella* is further distinguished from *Amphissites* and *Kirkbya* by the presence of the broad marginal band, and by the very coarse reticulations. Further, *Savagella* possesses only one node, if it bears any at all, and the one node is nearly central.

Savagella is distinguished from *Glyptopleura* in being much more convex, and in having a much less prominent overlap, with the left valve the larger, instead of the right, as in *Glyptopleura*. The surface markings of *Savagella* are reticulations, and though they may be quite coarse, they are not easily confused with the subparallel costae of *Glyptopleura*.

The species described by Girty in 1915 as *Glyptopleura rhomboidalis* from the Batesville sandstone of Arkansas, is properly designated *Savagella rhomboidalis*.

SAVAGELLA LINDAHLI (Ulrich)
Kirkbya lindahli ULRICH, *1891*, Jour. Cincinnati Soc. Nat. Hist., vol. 13, p. 207, pl. 18, figs. 6*a–c*.

Carapace oblong-rhomboidal in side view, dorsal margin straight, ventral margin straight or gently sinuate; anterior end well rounded ventrally, flattened dorsally forming an angle of at least 135 degrees with the hinge line; posterior end somewhat produced about one-third the carapace height from the dorsum, flatly curved above, truncated below. Dorsal view ovate, ends subacute, posterior the thicker, the subcentral nodes in gentle relief. Maximum height of carapace at the antero-cardinal angle, maximum thickness just in front of the center, except in very inflated shells (fertile females?) which have the maximum thickness just below and behind the center. Valves subequal, the left narrowly overlapping the right along the free margins and cardinal angles, and narrowly peripheral at the ends in right view. The ventral contact is usually impressed near the middle, forming a shallow depression in the venter. The free margin of each valve is bordered by a wide smooth band, that of the left valve bearing a deep, narrow furrow down the middle throughout its length. There is a large, deep central pit bordered anteriorly by a low node. Entire surface, except the marginal bands and the dorsum, covered with coarse irregular reticulations, the pits occasionally tending to fuse near the margins (pl. 24, fig. 7d) but normally rounded and widely spaced. Hinge contact straight, equalling two-thirds of the total shell length, and impressed in a furrow in the dorsum; the left valve bears a flange at its dorsal margin, which articulates with a groove in the right; there are apparently no hinge teeth. Valves thick.

Three specimens, one small, one large, and an inflated (female) shell, measure respectively:

(1) Length 1.35 mm.; height 0.87 mm.; thickness 0.86 mm.

(2) Length 2.04 mm.; height 1.16 mm.; thickness 1.1 mm.
(3) Length 2.15 mm.; height 1.17 mm.; thickness 1.6 mm.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Old Cleveland Quarry, Harrodsbury, Indiana; fairly common. Ulrich described the species from the Warsaw at Columbia, Illinois.

Types. Plesiotypes, no. M 331.

Family GLYPTOPLEURIDAE Girty

Genus GLYPTOPLEURA Girty, 1910

The Salem limestone is rich in species of *Glyptopleura*, and they are represented in the author's collections by hundreds of specimens. Careful comparison has shown that the different forms are so constant in the respective characters of the costae that these features alone furnish an admirable means of specific identification in most cases.

The Salem species of *Glyptopleura*, in harmony with the arguments presented in this paper, are here described as having the right valve the larger.

GLYPTOPLEURA PERBELLA Geis, n. sp.
Plate 25, figures 1*a*, *b*

Kirkbya (? *Barychilina*) *costata*, ULRICH (not McCoy), *1891*, Jour. Cincinnati Soc. Nat. Hist., vol. 13, no. 4, p. 208, pl. 18, figs. 2*a*, *b*.

Glyptopleura costata, CORYELL AND BLACKMIER (not McCoy), *1931*, Am. Midland Nat., vol. 12, no. 12, p. 510, pl. 1, figs. 1*a–c*.

Carapace oblong-rhomboidal in side view, anterior end flatly rounded forming an obtuse angle with the dorsum, posterior obliquely rounded, strongest curvature dorsal; dorsal margin long and straight, ventral margin gently convex. Dorsal view elongate, sides flattened, ends blunt. Valves unequal, the right overlapping the left at the cardinal extremities, and strongly visible beyond the left along the ventral periphery and ends, most strongly so at the postero-ventral angle; actual overlap slight. Since the dorsal and ventral margins are nearly parallel, the greatest height of carapace may vary from the median line to about one-fourth the shell length from either end. Carapace gently compressed dorsally, thickest usually just above the ventral contact about one-third the shell length from the posterior end, but very large specimens are inflated posteriorly with the greatest thickness above the middle at the posterior one-fourth. Surface marked by eleven costae which slope toward the anterior end, and a double pit above and in front of the center. The primary ridge starts near the postero-cardinal angle, passes through and divides the pit, and forks just in front of it. Above the primary ridge are three relatively straight costae grading in length to the shortest which lies at the antero-dorsal margin; below are five long costae which bend upwards at their ends and middle parts, and one very short ridge behind the pit and paralleling the primary ridge. The right valve has a marginal band. Hinge line long, straight, impressed; nature of the hinge contact uncertain.

Five specimens average: length 1.09 mm.; height 0.705 mm.; thickness 0.49 mm.

G. perbella as here described from

the Salem limestone, seems beyond doubt to be the same as the Chester form that Ulrich identified as *Kirkbya costata* (McCoy). A careful comparison of figures of McCoy's species and its different varieties reveals several salient differences, on the strength of which the American form is here separated from the British species. *G. costata* differs from *G. perbella* in its more nearly equivalved shell, its single individual pit, and its fewer, more widely spaced, and differently proportioned costae.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; fairly abundant.

Types. Holotype, no. M 332; paratypes, no. M 333.

GLYPTOPLEURA PARVACOSTATA Geis, n. sp.
Plate 25, figures 2*a–d*

Glyptopleura plicata CORYELL AND BLACKMIER (not Jones and Kirkby) *1931,* Am. Midland Naturalist, vol. 12, no. 12, p. 511, pl. 1, fig. 7, 7a, 7b.

Carapace oblong-rhomboidal in side view, dorsal and ventral margins straight; anterior end flat and obtusely angled dorsally, well rounded ventrally, posterior end obliquely rounded, sometimes rather flat just below the middle. There are two variations of this species, apparently due to sex modifications. In one the dorsal view is subclavate, sharply curved anteriorly, constricted just in front of the center; the posterior end is inflated and the thickened edge of the right valve interrupts an otherwise well rounded posterior extremity. The other form has flat sides in dorsal view, the anterior is blunt, and the posterior is constricted and subacute. Greatest height of valves at posterior one-fourth, greatest thickness above the middle of the posterior half in the inflated form, well inside the postero-inferior angle of the thin form. Valves unequal, the right overlapping the left slightly at the cardinal angles, and its thickened end and ventral margins visible beyond the left in left view, most strongly at the ventro-posterior angle; actual overlap narrow. Surface ornamentation consists of two sharp ridges, one starting at the postero-cardinal angle and following the periphery of the valve forward and downward, to terminate in front of the postero-dorsal end of which is expanded and may or may not be closed. The upper limb of the central ridge runs between two pits, one above and in front of the center of the valve, the other near the dorsal border and directly above first. Hinge long, straight, impressed between the dorsal ends of the outer ridges, contact apparently plain.

Average measurements of four inflated specimens: length 1 mm.; height 0.58 mm.; thickness 0.49 mm. Average measurements of four thin specimens: length 1 mm.; height 0.61 mm.; thickness 0.43 mm.

Coryell and Blackmier have related this species to *Glyptopleura plicata* (Jones and Kirkby). *G. plicata*, however, has the upper limb of the inner looped ridge below the pit, the ends of the loop are essentially equal, and the sides practically horizontal.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; common.

Types. Holotype, no. M 334; paratypes, no. M 335.

GLYPTOPLEURA CARINATA Geis, n. sp.
Plate 25, figures 3*a*, *b*

Carapace oblong-rhomboidal in side view, dorsal and ventral margins nearly straight; anterior end flat and obtusely angled dorsally, well rounded ventrally, posterior end broadly and obliquely rounded. In dorsal view anterior end sharply rounded, sides gently convex to a point about one-fifth the shell length, from the posterior end, behind which they are sharply constricted, with an acute termination. Carapace compressed toward the antero-superior angle, thickest near the postero-inferior margin, highest medially or toward the anterior end. Valves unequal, the right overlapping very slightly at the cardinal extremities, and very narrowly peripheral in left view ventrally and at the ends; actual overlap slight. Surface marked by a marginal ridge or rim, two pits, one just above the center, the other directly above the first, and six diagonal, inosculating costae sloping to the anterior end. The two primary costae join anteriorly, and are nodose posteriorly, the upper one lying between the two pits and bifurcating just in front of them, the point of bifurcation being marked by a slight node. There is one short ridge above the primary costae, one longer one between them, and two below. A characteristic feature is the compressed and unornamented posterior end. Hinge long, straight, impressed between the marginal rims; contact apparently plain.

Measurements of 4 specimens average: length 0.75 mm.; height 0.43 mm.; thickness 0.37 mm.

G. carinata is much like other forms in the Salem limestone. It differs in such easily perceptible features as number and character of costae, degree and position of inflation, etc. It

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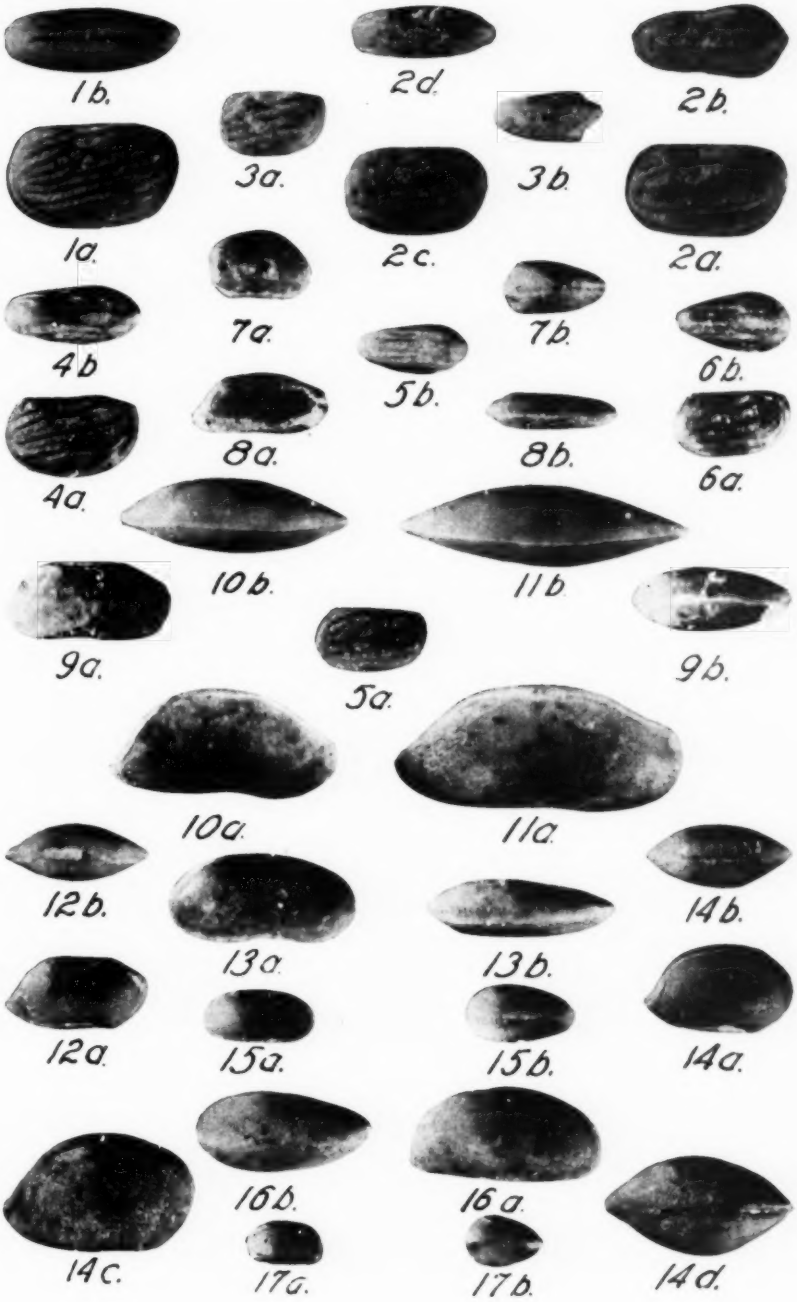
EXPLANATION OF PLATE 25
(All figures ×22)

FIGS. 1*a*, *b*—*Glyptopleura perbella* Geis, n. sp., *a*, left view; *b*, dorsal view.
2*a–d*—*Glyptopleura parvacostata* Geis, n. sp., *a*, left view; *b*, dorsal view of female; *c*, left view; *d*, dorsal view of male.
3*a*, *b*—*Glyptopleura carinata* Geis, n. sp., *a*, left view; *b*, dorsal view.
4*a*, *b*—*Glyptopleura elegantis* Geis, n. sp., *a*, left view; *b*, dorsal view.
5*a*, *b*—*Glyptopleura karli* Geis, n. sp., *a*, left view; *b*, dorsal view.
6*a*, *b*—*Glyptopleura karli* Geis, n. sp., *a*, left view; *b*, dorsal view of specimen with bifurcating middle ridge.
7*a*, *b*—*Healdia variolosa* Geis, n. sp., *a*, right view; *b*, dorsal view.
8*a*, *b*—*Bairdia compressa* Geis, n. sp., *a*, right view; *b*, dorsal view.
9*a*, *b*—*Bairdia bedfordensis* Geis, n. sp., *a*, right view; *b*, dorsal view.
10*a*, *b*—*Bairdia salemensis* Geis, n. sp., *a*, right view; *b*, dorsal view.
11*a*, *b*—*Bairdia permagna* Geis, n. sp., *a*, right view; *b*, dorsal view.
12*a*, *b*—*Bairdia depressa* Geis, n. sp., *a*, right view; *b*, dorsal view.
13*a*, *b*—*Bairdia subaequalis* Geis, n. sp., *a*, right view; *b*, dorsal view.
14*a–d*—*Bairdia compacta* Geis, n. sp., *a*, right view; *b*, dorsal view; *c*, right view; *d*, dorsal view of extraordinarily large specimen.
15*a*, *b*—*Microcheilus distortus* Geis, n. sp., *a*, right view; *b*, dorsal view.
16*a*, *b*—*Bythocypris norrisensis* Geis, n. sp., *a*, right view; *b*, dorsal view.
17*a*, *b*—*Microcheilus spinosus* Geis, n. sp., *a*, right view; *b*, dorsal view.



Geis—Salem (Mississippian) Ostracodes

is closely related to *G. regularis* Delo but is distinguished by its more prominent nodes at the posterior ends of the two major costae, and the more abruptly compressed posterior margin.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no. M 336; paratypes, no. M 337.

GLYPTOPLEURA ELEGANTIS Geis, n. sp.
Plate 25, figures 4*a*, *b*

Carapace oblong-rhomboidal in side view, dorsal and ventral margins nearly straight, anterior end flatly rounded and obtusely angled dorsally, evenly rounded ventrally, posterior end obliquely rounded. Sides flat in dorsal view, tapering to the blunt anterior end, sharply curved from the posterior one-third to the subacute rear termination. Carapace compressed toward the anterior superior angle, thickest near the posterior inferior margin, highest medially or toward the anterior end. Valves unequal, the right the larger, and narrowly peripheral along the ventral and end margins, most conspicuously thickened at the ventroposterior margin; actual overlap slight. Surface ornamentation consisting of two pits, one above and in front of the center, the second just above the first; each valve bears a marginal ridge and nine transverse, slightly tangential, inosculating costae, the primary ridge running between and dividing just in front of the two pits, its ends connecting with the fourth ridge below it, forming an elongate loop which is widest posteriorly. Above the loop, and below it, are two costae which unite with the marginal rim, the outer ridge in each case being short and inconspicuous. Within the loop are two long costae, and one short ridge, the latter behind the central pit. Hinge long, straight, impressed between the marginal ridges; contact apparently plain.

The measurements of five specimens average: length 0.93 mm.; height 0.52 mm.; thickness 0.45 mm.

G. elegantis differs from *G. carinata* in its greater number of costae and its more evenly convex surface. In *G. carinata* the posterior ends of the primary costae are noded, and the carapace is much more constricted posteriorly.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no. M 340; paratype, no. M 341.

GLYPTOPLEURA KARLI, Geis, n. sp.
Plate 25, figures 5*a*, *b* and 6*a*, *b*

This species resembles *G. elegantis* in outline, position of greatest thickness, height, and degree of overlap. Large specimens are apt to be inflated in the center of the posterior third, however, only the subcentral pit is present, and the character of the costae differs. Two strong ridges unite to form a flat sided, equally terminated ellipse, in the middle of which is a straight ridge whose extremities do not quite touch the ends

of the ellipse; three weaker ridges, one above and two below, unite with the primary ridges. The complete pattern may be considered as a broad oval, cut transversely by four more or less parallel lines. There is a marginal rim. The hinge is long, straight, and impressed; hinge contact apparently unornamented.

The measurements of four specimens average: length 0.83 mm.; height 0.47 mm.; thickness 0.36 mm.

A variation of this species (pl. 25, figs. 6a, b) differs only in the character of the straight ridge within the ellipse; it bifurcates posteriorly, the ends curved strongly forward till they parallel the main ridge. This variation is extremely rare, there being only one specimen of it in a collection of Salem ostracodes numbering about thirty thousand. Until more specimens are found to establish the species it is not distinguished from *G. karli*.

Locality. Old Cleveland Quarry, Harrodsburg, Indiana; rare, and found only near the top of the Salem limestone. Further search will be necessary to establish its complete vertical and horizontal distribution.

Types. Holotype, no. M 340; paratype, no. M 341.

Genus SANSABELLA Roundy, 1926

Roundy placed *Sansabella* among the Aparchitidae. It differs from *Glyptopleura* (which is definitely not in that family) chiefly in the absence of costae, hence *Sansabella* is here assigned to the family Glyptopleuridae.

In accordance with conclusions advanced in this paper, the Salem species is oriented with the right valve the larger in contrast with Roundy's earlier orientation.

SANSABELLA INFLATA Geis, n. sp.
Plate 23, figures 3*a*, *b*

Carapace oblong-rhomboidal in side view, dorsal margin straight or slightly sinuous, ventral margin flatly convex, anterior end flattened dorsally to form an obtuse angulation at the antero-superior angle, posterior end truncated ventrally. Dorsal view subcuneate, anterior acute, posterior quite blunt. Maximum height median to anterior, maximum thickness just inside the postero-inferior contact, carapace compressed antero-dorsally. Valves unequal, the right one the larger, and peripheral in left view along the free margin; actual overlap slight, greatest at the cardinal extremities. Surface smooth, except for a deep pit just above and in front of the center. Hinge somewhat shorter than the greatest shell length, straight, its posterior end deeply impressed in the dorsum; exact nature of the hinge contact uncertain.

Measurements of three specimens average: length 0.7 mm.; height 0.5 mm.; thickness 0.47 mm.

S. inflata differs from *S. sulcata* Roundy in the absence in the former of the sulcus, in its less extended posterior extremity, and in the position of maximum thickness. It has a much deeper pit than *S. amplectans* Roundy, does not possess a submarginal furrow in the larger valve, and differs in the position of maximum thickness.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; fairly common.

Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no. M 342; paratypes, no. M 343.

Superfamily CYPRIDACEA
Family BAIRDIDAE Ulrich and Bassler
Genus HEALDIA Roundy, 1926

HEALDIA VARIOLOSA Geis, n. sp.
(Plate 25, figures 7*a*, *b*)

Carapace in side view subreniform, dorsum well arched, with a short posterior slope and longer and steeper anterior slope, ventral margin slightly concave; anterior end low and evenly rounded, posterior end high and flatly rounded, with a slight angulation or node at its lowest point. Dorsal view cuneate. Greatest height of valves submedian, greatest thickness at the posterior one-fourth. The right valve sometimes possesses a subcentral pit, and each valve bears a strong furrow paralleling the posterior contact margin, the lower end of the furrow usually terminated by a short spine or node. Valves unequal, the left one larger and peripheral in right view around the entire carapace, narrowly so anteriorly posteriorly. Surface smooth.

Measurements of four representative specimens average: length 0.68 mm.; height 0.48 mm.; thickness 0.4 mm.

This species is a disconcertingly unstable one, variation being strong. Only a relatively few specimens possess all the characters described above, the rest varying in one or more particulars, but so irregularly that the differences cannot be used as a basis of further specific or varietal differentiation. The tendency of the individuals to vary is all the more striking in that it cannot be attributed to physical deformation by extraneous forces. Remarkably few of the Salem fossils have been crushed by compression of the formation at any time, though the surfaces of the specimens are frequently worn, and much of the matrix of the limestone is fragmental.

H. variolosa is distinguished from *H. ackersi* Delo by its greater length, by its more produced anterior portion, and by having the spines much less prominent, or absent. *H. marginata* Harlton differs from *H. variolosa* in the absence of the posterior furrows.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; present, though comparatively rare, at all levels; Old Cleveland Quarry, Harrodsburg, Indiana; rare, and found only in the upper one-third of the formation.

Types. Holotype, no. M 344; paratypes, no. M 345.

Genus BAIRDIA McCoy, 1844

BAIRDIA PERMAGNA Geis, n. sp.
Plate 25, figures 11*a*, *b*

Carapace large, elongate subdeltoidal in side view; dorsal margin arched, with a slightly concave anterior slope, and a longer, steeper, and gently concave posterior slope; ventral margin somewhat sinuate in the middle; anterior end well rounded, its strongest curvature dorsal, and without angulation, posterior end acute, the beak tending very

slightly to turn upwards. Dorsal view lanceolate, ends acute. Carapace highest at the middle, thickest just below and in front of the center, compressed ventrally to the sharp lower margin. Valves unequal, the left rising above the right strongly at the hinge-line, progressively less down the slopes; ventral overlap slight, and confined to the central half of the margin. Hinge short, straight, horizontal, occupying the central two-fifths of the shell length; contact simple. Surface smooth, valves thin.

Average measurements of 4 specimens: length 1.86 mm.; height 0.816 mm.; thickness 0.58 mm.

B. permagna is quite similar to the common British Carboniferous species, *B. curta* McCoy. The British form, however, has a higher and blunter anterior, with a sharper ventral curvature at the anterior end, and a dorsal angulation; the beak is more produced, and the hinge line is curved, and inclined posteriorly.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Walsh and P.M.B. Quarries, Bedford, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana. *B. permagna* is a common species of the Salem ranging from top to bottom, wherever it occurs.

Types. Holotype, no. M 346; paratype, no. M 347.

BAIRDIA SALEMENSIS Geis, n. sp.
Plate 25, figures 10*a*, *b*

Carapace strong, elongate-subtriangular in side view; dorsal margin broadly arched, posterior slope long and steep, concave at its lower end, anterior slope slightly shorter, more gently inclined, nearly straight; ventral margin sinuate at the middle; posterior end extended to form a long low beak, anterior end strongly truncated ventrally, but without dorsal angulation. In dorsal view the ends are acute, anterior one somewhat compressed. Carapace highest medially or near the posterior end of the hinge-line, thickest just in front of the center. Valves unequal, the left one the larger, and forming the periphery in right view along the dorsal margin and slopes, and along the sinuate portion of the ventral contact; actual overlap negligible. Hinge-line simple and straight, occupying a little less than one-half the shell length, somewhat posterior to the middle. Surface smooth, valves thin.

The measurements of four typical specimens average: length 1.45 mm.; height 0.685 mm.; thickness 0.55 mm.

This species differs from *B. permagna* in having a steeper postero-dorsal slope and more acute beak, in being thicker in proportion to its height, and in being stronger at and below the postero-cardinal angle.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Old Cleveland Quarry, Harrodsburg, Indiana; and Walsh and P.M.B. Quarries, Bedford, Indiana; fairly common at all horizons.

Types. Holotype, no. M 348; paratype, no. M 349.

BAIRDIA BEDFORDENSIS Geis, n. sp.
Plate 25, figures 9*a*, *b*

Carapace strong, subquadrate in side view, dorsum straight, ventral

outline gently concave. Postero-dorsal slope short, abrupt, terminated by a strong, rounded, subventral beak, antero-dorsal slope gentle, anterior end nearly evenly curved. Greatest height of carapace median, greatest thickness below and in front of the center. Dorsal view compressed ovate, sides nearly parallel, anterior end sharply rounded, posterior broader, beak spine-like in dorsal view. Valves unequal, the left one the larger; apparent overlap strong on the dorsal slopes, weak on the dorsal and sinuate portion of the ventral margins; actual overlap slight. Dorsal and ventral margins compressed, flattened above and below; carapace inflated along the posterior slope, which is flattened in end view, the beak sharply constricted. Hinge simple, straight, occupying the central half of dorsum. Surface smooth, valves thick. A few specimens seem to have an irregularly, coarsely pitted surface, probably due to weathering.

Average measurements of four typical specimens: length 1 mm.; height 0.48 mm. thickness 0.46 mm.

This species is characterized by its faint dorsal overlap, flattened venter and dorsum, strong posterior, and laterally constricted beak. It does not closely resemble any species known to the author. It is much shorter than *B. depressa*.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Old Cleveland Quarry, Harrodsburg, Indiana; and Walsh and P.M.B. Quarries, Bedford, Indiana; comparatively rare.

Types. Holotype, no. M 350; paratype, no. M 351.

BAIRDIA COMPACTA Geis, n. sp.
Plate 25, figures 14*a–d*

Carapace short, dorsum broadly arched in side view, with a long, steep, slightly concave posterior slope, and shorter convex anterior slope; ventral margin straight or shallowly sinuate, posterior end produced into a short, sharp, subventral beak, anterior end high and obliquely rounded. Ends acute in dorsal view, posterior sharply and anterior more gently compressed. Carapace highest one-third of its length from the anterior end, thickest at or in front of the center. Valves unequal, the left one the larger, apparent overlap strong at the dorsal and central half of the ventral margins; actual overlap negligible. Hinge simple, short, straight, inclined posteriorly, its surface expression only slightly if at all impressed. Surface smooth, valves moderately thick.

Measurements of four normal specimens average: length 0.98 mm.; height 0.53 mm.; thickness 0.45 mm. Two extraordinarily large and obese specimens average: length 1.3 mm.; height 0.86 mm.; thickness 0.75 mm.

B. compacta is strongly reminiscent of the common British Carboniferous species *B. plebeia* Reuss, but has a much steeper posterior slope, a shorter anterior slope, and shows no antero-ventral overlap.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Old Cleveland Quarry, Harrodsburg, Indiana; and Walsh and P.M.B. Quarries, Bedford, Indiana; fairly common.

Types. Holotype, no. M 352; paratypes, no. M 353.

BAIRDIA COMPRESSA Geis, n. sp.
Plate 25, figures 8*a*, *b*

Carapace elongate in side view, dorsal margin gently arched, posterior slope long, slightly concave, anterior slope quite gentle, a unit with the dorsum; anterior end evenly rounded, posterior end prolonged into a sharply rounded, subventral beak; venter sinuate. Dorsal view slender, sides flat, gently compressed to an acute termination anteriorly, posterior end acute and more sharply compressed. Greatest height and thickness of carapace median or slightly posterior. Valves unequal, the left one narrowly peripheral in right view along the whole dorsal margin, and along the concave portion of the ventral margin. Hinge short, less than half the length of the shell, posteriorly placed. Surface smooth, valves thin.

Average measurements of five specimens: length 0.924 mm.; height 0.38 mm.; thickness 0.26 mm.

B. compressa can be distinguished from *B. bedfordensis* by its emaciated appearance and its longer posterior projection; it is also more nearly equivalved.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; nowhere abundant.

Types. Holotype, no. M 354; paratype, no. M 355.

BAIRDIA SUBAEQUALIS Geis, n. sp.
Plate 25, figures 13*a*, *b*

Carapace oblong-elliptical in side view, dorsal margin arched, slopes gentle, posterior one somewhat steeper; ventral margin concave, ends obliquely rounded, anterior end the higher. Dorsal view lanceolate, sides flattened, ends subacute, posterior one the broader. Greatest thickness of carapace central to posterior one-fourth, greatest height median. Valves unequal, the left one peripheral in right view along the entire margin, though only slightly at the anterior end; actual overlap slight. Hinge simple, two-fifths of carapace in length, situated closer to the posterior end. Surface smooth.

Average measurements of four specimens: length 1.3 mm.; height 0.65 mm.; thickness 0.45 mm.

B. subaequalis shows some resemblance to *B. shideleri* Delo, but is distinguished by the median position of the ventral sinuosity, and by the more nearly parallel dorsal and ventral margins.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no. M 358; paratype, no. M 359.

BAIRDIA DEPRESSA Geis, n. sp.
Plate 25, figure 12*a*, *b*

Carapace short, compressed-hexagonal in side view, dorsal margin straight, gently inclined to the posterior, posterior slope steep, concave, anterior slope shorter, straight; ventral margin slightly sinuate in the middle, flatly curved posteriorly to the point of the sharp beak, and anteriorly to the obtuse anterior angulation. Ends acute in dorsal view, sides well rounded. Carapace highest

at the anterior end of the hinge, thickest centrally. Valves unequal, the left peripheral in right view except at the hinge. Hinge short, straight, sloping posteriorly, impressed, and situated in the center of the dorsum. The valves rise above the hinge contact on either side, but the upper margin of the left valve inclines toward the posterior more rapidly than the right, so that the right is narrowly visible beyond the left at the posterior end of the hinge in left view. The center of the ventral contact is more deeply sinuate than the lower shell margin, so that the ventral margin of the right valve is normally quite strongly angled at a point one-third of the shell length from the anterior. Surface smooth, valves thick.

Average measurements of six specimens: length 0.98 mm.; height 0.53 mm.; thickness 0.46 mm.

B. depressa is somewhat similar to the Chester species *B. cestriensis* Ulrich,[9] the two species sharing the impressed hinge contact (according to Ulrich's type fig. 6, c) and the compressed hexagonal outline (fig. 6, b). *B. cestriensis*, however, seems to be devoid of the antero-ventral angulation of the right valve, and the margin of the right valve does not rise above the left at the posterior end of the hinge contact. It seems doubtful that the specimens illustrated by Ulrich's figures 7a and 7b can be the same species as his figures 6a and 6c. Certainly they show no resemblance to *B. depressa* as the larger forms do.

[9] *Jour. Cincinnati Soc. Nat. Hist.*, vol. 13, 1891, p. 210, pl. 17, figs. 6–7.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Walsh and P.M.B. Quarries, Bedford, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; nowhere abundant.

Types. Holotype, no. M 356; paratypes, no. M 357.

Genus Bythocypris H. B. Brady, 1880

It is probable that some of the Salem forms identified as *Bythocypris* do not belong to that genus. However, until a careful study is made of all the forms placed here by various authors and the proper revisions are made, it is considered best to associate the new species with Brady's genus.

Bythocypris marginifera Geis, n. sp.
Plate 26, figures 2*a*, *b*

Carapace inflated, reniform in side view, dorsum strongly arched, ends obliquely rounded, venter sinuate somewhat in front of the middle; posterior end slightly higher than anterior. Ends subacute in dorsal view, sides well curved. Dorsum inflated, venter gently compressed. Valves unequal, the left one the larger and peripheral along the entire margin in right view, most strongly so dorsally; actual overlap negligible. Greatest height of carapace median, greatest thickness central. Hinge short, straight, posteriorly inclined, and situated slightly posterior to the middle. Surface smooth, valves thick.

Measurements of six specimens average: length 1.55 mm.; height 1 mm.; thickness 0.8 mm.

B. marginifera is shorter than *B. bilobata* Münster, and has a stronger

apparent dorsal overlap. It differs from *B. carbonica* Jones and Kirkby in being sinuate ventrally, and more broadly arched dorsally. *B. devonica* Ulrich has flattened sides and is thicker ventrally.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; relatively common.

Type. Holotype, no. M 360; paratype, no. M 361.

BYTHOCYPRIS NORRISENSIS Geis, n. sp.
Plate 25, figures 16*a*, *b*

Carapace in side view almost semicircular, dorsal margin broadly arched, ventral margin straight, and equalling the greatest length of the shell. Anterior end rounded, with obtuse antero-inferior angulation, postero-dorsal slope extended abruptly to the ventral margin, forming a distinct postero-inferior angulation of approximately ninety degrees. Ends broadly acute in dorsal view, anterior gently compressed, sides well rounded. Carapace highest medially, thickest behind the center. Valves unequal, the left one slightly larger and very narrowly peripheral in right view along the end and ventral margins; the left valve strongly overlaps the right ventrally. Hinge simple, short, and median. Surface smooth, valves thin.

Measurements of six specimens average: length 1.15 mm.; height 0.7 mm.; thickness 0.64 mm.

The long straight venter, and moderate apparent overlap of *B. norrisensis* distinguish it easily from *B. lydeae.* It differs from *B. pediformis* Knight in having a lower anterior and no dorsal overlap.

Localities. Railroad cut at Sperger Hill, Norris, Indiana; and Old Cleve land Quarry, Harrodsburg, Indiana· vertical distribution covers the entir Salem, but nowhere common.

Types. Holotype, no. M 362; para types, no. M 363.

BYTHOCYPRIS LYDEAE Geis, n. sp.
Plate 26, figures 1*a*, *b*

Carapace in side view elongate-ovate, dorsal margin broadly arched, ventral margin straight in the anterior three-fourths, the posterior one-fourth being deflected sharply upward; posterior end higher than the anterior, with a steep dorsal slope

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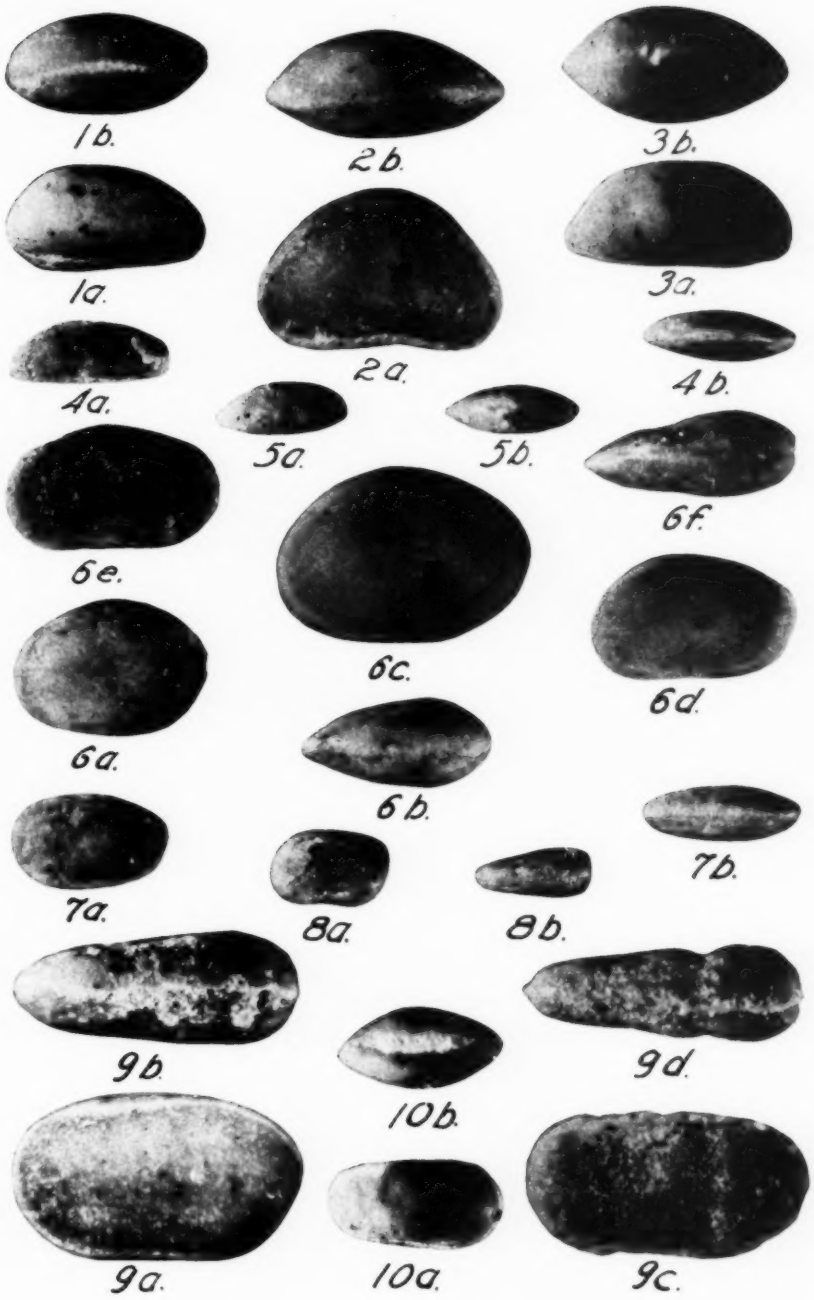
EXPLANATION OF PLATE 26
(All figures ×22)

FIGS. 1*a*, *b*—*Bythocypris lydeae* Geis, n. sp., *a*, right view; *b*, dorsal view.
2*a*, *b*—*Bythocypris marginifera* Geis, n. sp., *a*, right view; *b*, dorsal view.
3*a*, *b*—*Acratia deloi* Geis, n. sp., *a*, right view; *b*, dorsal view.
4*a*, *b*—*Pontocypris coryelli* Geis, n. sp., *a*, right view; *b*, dorsal view.
5*a*, *b*—*Pontocypris billingsella* Geis, n. sp., *a*, right view; *b*, dorsal view.
6*a*–*f*—*Cytherella savagei* Geis, n. sp., *a*, left view; *b*, dorsal view; *c*, left view of very large specimen; *d*, left view of elongate specimen; *e*, left view; *f*, dorsal view of cast of fig. 6*c*.
7*a*, *b*—*Cytherella spergenensis* Geis, n. sp., *a*, left view; *b*, dorsal view.
8*a*, *b*—*Cytherella emaciata* Geis, n. sp., *a*, left view; *b*, dorsal view.
9*a*–*d*—*Cavellina glandella* (Whitfield), *a*, left view; *b*, dorsal view; *c*, left view; *d*, dorsal view of cast.
10*a*, *b*—*Kellettella incarinata* Geis, n. sp., *a*, left view; *b*, dorsal view.



Geis—Salem (Mississippian) Ostracodes

and sharply curved termination. Carapace ovate in dorsal view, anterior end more sharply rounded. Greatest height and thickness at the posterior one-third. Valves unequal, the left one the larger, unevenly peripheral in right view, most strongly at the antero-dorsal slope and postero-ventral angle where the actual overlap is also greatest. Hinge short, occupying one-third of the dorsum, nearer the posterior end, the contact consisting of a groove in the left valve into which the right valve fits. Margins of valves thickened. Surface smooth, valves thick.

Measurements of six specimens average: length 1.4 mm.; height 0.76 mm.; thickness 0.67 mm.

B. lydeae is distinguished from *B. lunata* Jones and Kirkby by the greater valve inequality, and by the upward sloping postero-ventral margin. Its overlap is quite irregular as compared with *B. pediformis* Knight.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Old Cleveland Quarry, Harrodsburg, Indiana; and Walsh Quarry, Bedford, Indiana; present but not common, from top to bottom of the Salem formation at the localities mentioned.

Types. Holotype, no. M 364; paratypes, no. M 365.

Genus MICROCHEILUS Geis, n. gen.

Carapace tumid, oblong in side view, ventral margin straight, dorsal broadly arched, ends subequal in height and rather evenly rounded. Dorsal view ovate, posterior broadly, anterior sharply rounded. Maximum height of carapace median to anterior, maximum thickness near the posterior quarter and usually greater than the height. The maximum convexity is often above the middle in the right valve and below it in the left, so that the end view has an obliquely compressed appearance. Valves unequal, the left the larger, narrowly and rather evenly peripheral in right view around the entire margin, and strongly overlapping the right ventrally. Hinge straight, equalling half the total shell length, and simple. Valves moderately thin. Surface smooth or punctate.

The name is derived from the Greek, *micros*-small, and *cheilos*-lip or rim.

Genotype: *Microcheilus distortus* Geis, n. sp.

Range: Silurian (?), Devonian, Mississippian.

This genus has been confused in the past with *Xestoleberis*. It differs from *Xestoleberis* in the very strong ventral overlap, in the simple hinge contact, and in the relatively equal height of the ends. Modern species of *Xestoleberis* do not show the left valve evenly peripheral in right view. The Silurian species, *Cythere corbuloides* Jones and Hall, was described in 1869, but in 1880 Brady, who was well acquainted with the work of the English authors, still insisted that the *Xestoleberis* was of comparatively recent development paleontologically. As a result, when Jones and Kirkby described *Xestoleberis* (?) *subcorbuloides* in 1885, and noted its relation to *C. corbuloides*, they indicated the doubtful nature of the identification. *X.* (?) *subcorbuloides*

Jones and Kirkby, *Bythocypris punctulata* Ulrich, and perhaps *C. corbuloides*, should be referred to the genus *Microcheilus*.

Microcheilus differs from *Pachydomella* in having thinner valves, with contact edges only slightly thickened. There is no pit. It differs from *Barychilina* in having thinner valves, in having the left valve the larger, and in the absence of the pit.

MICROCHEILUS DISTORTUS Geis, n. sp.
Plate 25, figures 15*a*, *b*

Carapace tumid, oblong in side view, dorsal margin very slightly arched, ventral margin long and straight, anterior and posterior ends about equal in height, and evenly rounded. Dorsal view ovate, posterior end broadly, and anterior sharply curved. Greatest height of complete carapace median and less than greatest thickness, which is at the posterior one-fourth; the position of greatest convexity, however, differs in the two valves, it being slightly ventral in the left, and dorsal in the right, so that a posterior view or cross section has an obliquely distorted appearance. Valves unequal, the left one the larger, evenly and narrowly peripheral in right view, and strongly overlapping the right ventrally. Hinge contact simple. Surface smooth.

Measurements of six specimens average: length 0.68 mm.; height 0.37 mm.; thickness 0.41 mm.

M. distortus is more elongate than *M. subcorbuloides* (Jones and Kirkby). The Devonian species, *M. punctulatus* (Ulrich), is somewhat shorter than *M. distortus*, and has a punctate surface. Girty[10] correlates a single ostracode in his collection with *X. subcorbuloides*. Girty's specimen may be identical with *M. distortus*.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Old Cleveland Quarry, Harrodsburg, Indiana; and Walsh and P.M.B. Quarries, Bedford, Indiana; fairly common.

Types. Holotype, no. M 366; paratypes, no. M 367.

MICROCHEILUS SPINOSUS Geis, n. sp.
Plate 25, figures 17*a*, *b*

Carapace minute, obese, lateral view oblong, dorsal margin flatly arched, venter straight; ends obliquely rounded, strongest curvature dorsal at the posterior, ventral at the anterior end. Dorsal view ovate, anterior narrowly, and posterior very broadly rounded. Greatest height of complete carapace at anterior one-third, and less than the greatest thickness, which is at the posterior one-third. The two valves vary in position of greatest convexity, it being slightly ventral in the left valve, and dorsal in the right, so that the carapace seems obliquely distorted in posterior view. Valves unequal, the left one the larger, evenly peripheral in right view except at the postero-ventral angle, where it is obscured by a spine on the right valve. The left valve overlaps the right slightly at the cardinal angles, and strongly ventrally. There is often a deep notch in the margin of the left valve at the position of the spine on the right.

[10] Girty, G. H., Micro-fauna of the Mississippian formations of San Saba County, Texas, *U. S. Geol. Survey, Prof. Paper 146*.

Hinge contact simple. Surface smooth.

Measurements of four typical specimens average: length 0.48 mm.; height 0.26 mm.; thickness 0.32 mm.

M. spinosus is shorter than *M. distortus* and is further distinguished from it by the spine.

Localities. Old Cleveland Quarry, Harrodsburg, Indiana; and Railroad cut at Spergen Hill, Norris, Indiana; rare.

Types. Holotype, no. M 368; paratypes, no. M 369.

Genus ACRATIA Delo, 1930

AQRATIA DELOI Geis, n. sp.
Plate 26, figures 3*a*, *b*

Carapace obese, transversely semielliptical in side view, carapace longest near the ventral margin; dorsal margin strongly arched, anterior end rounded, posterior end slightly produced; ventral margin straight to slightly sinuate in the central one-half, gently and flatly angled upward posteriorly, and more strongly so anteriorly, the antero-ventral margin usually gently concave. Dorsal view obese, ends acute. Greatest height of carapace median, and less than the greatest thickness which is central in normal specimens, slightly posterior in very large specimens. Valves unequal, the left one the larger, and narrowly peripheral in right view except at the dorsal margin; actual overlap strong ventrally, moderate along the antero-dorsal slope and cardinal angles. Hinge simple, short, slightly impressed. Surface smooth.

Average measurements of five specimens: length 1.42 mm.; height 0.68 mm.; thickness 0.72 mm.

A. deloi is easily distinguished from *A. typica* Delo and *A. magna* Delo by its more evenly rounded dorsum, its greater thickness, and its less abrupt antero-ventral deflection.

Localities. Old Cleveland Quarry, Harrodsburg, Indiana; Railroad cut at Spergen Hill, Norris, Indiana; and Walsh and P.M.B. Quarries, Bedford, Indiana; common.

Types. Holotype, no. M 370; paratypes, no. M 371.

Genus PONTOCYPRIS M. Sars, 1865

PONTOCYPRIS BILLINGSELLA Geis, n. sp.
Plate 26, figures 5*a*, *b*

Carapace elongate in side view, dorsal margin broadly arched, anterior rounded, posterior produced and acute, ventral margin gently convex; greatest length of carapace below the middle line, greatest height and thickness approximately equal, yielding a nearly circular cross-section. Valves subequal, the left slightly larger than the right, narrowly peripheral and slightly overlapping ventrally. Hinge contact simple and arched. Surface smooth, valves thin.

Measurements of four specimens average: length 0.94 mm.; height 0.33 mm.; thickness 0.32 mm.

In such characterless shells specific lines are difficult to draw, the best criteria seeming to be proportions, which it is believed are here accurately recorded, and such subtleties of outline as are better pictured than put in words. The higher anterior and less produced posterior distinguish it from *P. acuminata* Ulrich.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; quite rare.

Types. Holotype, no. M 372; paratype, no. M 373.

PONTOCYPRIS CORYELLI Geis, n. sp.
Plate 26, figures 4*a*, *b*

Carapace transversely semi-subelliptical, ventral margin straight, dorsal broadly curved, produced posteriorly to a subacute extremity, rounded anteriorly. Dorsal view elongate, ends acute. Maximum height at the anterior two-fifths, maximum thickness central. Valves unequal, the left narrowly overlapping the right ventrally. Hinge short, situated slightly anteriorly, contact simple; valves thin.

Average measurements of three specimens: length 0.98 mm.; height 0.32 mm.; thickness 0.3 mm.

This species differs from *P. billingsella* in being longer, and less acute posteriorly. It is more elongate than *P. mawii* Jones, and less acute posteriorly than *P. acuminata* Ulrich.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; rare.

Types. Holotype, no. M 374; paratype, no. M 375.

Family CYTHERELLIDAE M. Sars
Genus CYTHERELLA Jones, 1848
CYTHERELLA SAVAGEI Geis, n. sp.
Plate 26, figures 6*a–f*

Outline of carapace oblong-ovate, anterior end nearly evenly rounded, posterior end truncated ventrally, dorsal margin highly arched, ventral straight, or slightly sinuate. Carapace highest at or near the middle, thickest one-third to one-fourth its length from the posterior extremity. Dorsal view expanded, rounded posteriorly, compressed anteriorly to an acute termination. Valves unequal, the right valve overlapping the left ventrally and dorsally; ventral contact of the valves sinuate, the right valve extending downward from the contact to form a more nearly straight profile, the left valve expanding abruptly laterally to form a narrow and short, almost flat, area to the left of the ventral contact. The dorsal margin of the right valve is usually thickened to form a feature at this point, large specimens possessing a shallow furrow below it paralleling the dorsal margin in its central portion. Both valves are usually marked in the center of the dorsal half by a broad shallow depression. The valves are thickened internally to form a broad ridge in the posterior quarter of each valve, running from the ventral contact half way to the dorsal margin; a lower ridge rises from a corresponding point in the anterior quarter and swings posteriorly to the muscle scar, which is a broad node just in front of and above the center. Hinge short, the right valve grooved to receive the left. Surface smooth, valves thick.

Proportions vary somewhat. Measurements of the specimens figured are:

FIG. 6*a*—length 1.2 mm.; height 0.9 mm.; thickness 0.65 mm.
FIG 6*c*—length 1.53 mm.; height 1.05 mm.; thickness 0.73 mm.
FIG. 6*d*—length 1.35 mm.; height 0.9 mm.; thickness 0.66 mm.

C. savagei is quite similar to *C. extuberata* (Jones and Kirkby), reported by them from the Lower Carboniferous of Northampton and Northumberland, but differs in having the greatest height nearer the anterior end. Further, if the description and figures can be relied upon, *C. extuberata* is less strongly truncated postero-ventrally, and lacks the surface irregularities of *C. savagei*.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; Walsh and P.M.B. Quarries, Bedford, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana.

Types. Holotype, no. M 376; paratype, no. M 377.

CYTHERELLA EMACIATA Geis, n. sp.
Plate 26, figures 8*a*, *b*

Carapace minute, emaciated, subrhomboidal in side view, dorsum gently arched, ventral outline slightly concave; anterior broadly rounded, with strongest curvature ventral, posterior end truncated ventrally but without dorsal angulation. Dorsal view cuneate, posterior broad, anterior acute, sides flat or even slightly concave in the middle. Greatest height median, greatest thickness in the center of the posterior one-fourth. Valves unequal, the right overlapping dorsally and ventrally, though not conspicuously. Hinge straight, long, the right valve shallowly grooved to receive the left. Shell smooth, valves thin.

Average measurements of 3 individuals: length 0.66 mm.; height 0.44 mm.; thickness 0.22 mm.

As far as the author has determined, this species is not likely to be confused with any other. Its small size and emaciated appearance serve to distinguish it from any in the Salem limestone collections.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana.

Types. Holotype, no. M 378; paratype, no. M 379.

CYTHERELLA SPERGENENSIS Geis, n. sp.
Plate 26, figures 7*a*, *b*

Carapace quadrate-elliptical in side view, dorsal and ventral margins gently and evenly convex, anterior end broadly curved, posterior slightly truncated ventrally. Dorsal view lanceolate, sides gently convex, ends sharply rounded or subacute. Carapace somewhat compressed dorsally, highest just behind the middle, thickest below and behind the center. Valves unequal, the right one the larger, and narrowly peripheral dorsally and ventrally in left view; actual overlap negligible. Internal characters as in *C. savagei*, though much reduced. Hinge short, simple; surface smooth.

Four representative specimens average in measurements: length 1 mm.; height 0.6 mm.; thickness 0.4 mm.

C. spergenensis is distinguished from the Chester species, *C. ovatiformis*, Ulrich, by its thinner posterior, and the less conspicuous inequality of the valves.

Localities. Old Cleveland Quarry, Harrodsburg, Indiana; Railroad cut at Spergen Hill, Norris, Indiana; nowhere common.

Types. Holotype, no. M 380; paratype, no. M 381.

Genus CAVELLINA Coryell, 1928

CAVELLINA GLANDELLA (Whitfield)
Plate 26, figures 9*a–d*

Cytherellina glandella WHITFIELD, *1882*, Am. Mus. Nat. Hist., Bull. 3, vol. 1, p. 54, pl. 9, figs. 28 and 29.—HALL, *1882*, Ind. Dept. Geol. and Nat. Res., 12th Ann. Rept., pl. 32, figs. 28–29 (figures only).—CUMMINGS AND BEEDE, *1905*, Dept. Geol. and Nat. Res. 30th Ann. Rept., pl. 26, figs. 28–29 (figures only).

Cytherella glandella GIRTY, *1915*, U. S. Geol. Survey, Bull. 593, p. 136.

Of Whitfield's four type specimens now in the American Museum of Natural History, two are *Bythocypris lydeae* Geis, n. sp.,[11] and two are *Cavellina* of the form here accepted as *C. glandella*. As a result, Whitfield's figures and description are curious blendings or mixtures of these two species. Because there is perhaps more of the latter species in his description, and since his figures and selection of the genus point a little more strongly to it, it seems preferable to retain it as *C. glandella*. Whitfield's description is quoted:

> Carapace minute, elongate ovate, a little wider at one (posterior?) end and also more ventricose, while being compressed gradually toward the anterior extremity, presenting a somewhat cuneate aspect in profile. Upper and lower margins nearly equally curved; ends neatly rounded, length about twice the thickness of the middle of the valves. Valves nearly equal, scarcely overlapping at their edges even on the basal margin; the hinge-line smooth under an ordinary magnifier, but with scarcely distinguishable. Surface of the valves a faint sulcus crossing them just behind the middle, and a slight tubercle between it and the broader end.
>
> There is some doubt as to the true generic relations of this species. It seems more nearly related to *Cytherellina* than to any other which I can find, although the slight inequality of the valves required under the diagnosis of that genus does not appear on any of the very few specimens which I have observed. There is some very little variation in the form of the different specimens in their proportionate length and breadth, and also in the regularity of curvature. Length of the largest specimen about eight one-hundredths of an inch.

As corrected by the author: Carapace quadrate-elliptical in side view, dorsal margin gently arched, ventral slightly sinuate; anterior margin broadly rounded with strongest curvature dorsal, posterior end obliquely truncated. Dorsal view cuneate, anterior end sharply, posterior bluntly rounded, sides straight or gently concave or convex. Greatest height median; greatest thickness variable, a large number of specimens grading uninterruptedly from a form in which the thickest portion of the carapace is just below the center, to a form in which the posterior quarter is expanded. In the latter specimens, there is a shallow furrow perpendicular to the shell length at a line one-fourth of the shell length from the posterior end. In all specimens the dorsal margin is slightly compressed near its middle. Surface otherwise smooth. Valves unequal, the right valve the larger, and forming the periphery along the ventral and dorsal margins in left view; actual overlap slight except at the anterior end of the hinge line. Posterior quarter of carapace partially isolated internally

[11] The identification of these two specimens is uncertain. The specimens were imbedded in glue to show the dorsal surfaces only, and it was thought best not to disturb them. One or both may be *Bythocypris norrisensis* Geis, n. sp., as dorsal views of the two species are much alike.

by a ridge in each valve corresponding to the external furrow, which is sharp towards the dorsal margin, broadening out towards the anterior as it approaches the ventral margin; a circular node for muscle attachment lies slightly in front of the center, where it is joined by a broad, low swelling which rises at the anteroventral margin. Another such swelling extends from the node to a position slightly forward on the dorsal margin. In the thinner specimens, all internal features except the node are reduced. Hinge straight, simple, the left valve fitting into a furrow in the right. Valves thick.

Average measurements of four specimens whose greatest thickness is subcentral: length 1.72 mm.; height 0.98 mm.; thickness 0.65 mm. Average measurements of four specimens with expanded posteriors: length 1.73 mm.; height 0.97 mm.; thickness 0.72 mm.

Localities. Present, though never abundant at all horizons of Salem outcrops at: Railroad cut at Spergen Hill, Norris, Indiana; Old Cleveland Quarry, Harrodsburg, Indiana; and Walsh and P.M.B. Quarries, Bedford, Indiana.

Types. Plesiotypes, no. M 382.

Superfamily CYTHERACEA
Family CYTHERIDAE Zenker
Genus KELLETTELLA Delo, 1930

The genotype, *Kellettella naviculata* Delo, is characterized by a strong ridge on each valve roughly parallel to the free margin. Having only the one species from which to deduce generic valves, Delo regarded the ridges of generic importance. The Salem species described below compares so well with *K. naviculata* in all other characteristics that its generic identity seems well established. On that basis the ridges of *K. naviculata* are given specific value only.

KELLETTELLA INCARINATA Geis, n. sp.
Plate 26, figures 10*a*, *b*

Carapace oblong-ovate in side view, dorsal margin gently arched, ventral edge shallowly sinuate, ends obliquely rounded, with strongest curvatures dorsal. Dorsal view lanceolate, ends equal and acute. Carapace highest at the posterior one-fourth, thickest just above the center. Valves unequal, the right valve the larger, narrowly peripheral in left view at its ends, more strongly ventrally; actual overlap moderate at the cardinal angles and the ventral margin. The right valve is marked ventrally and laterally by an indistinct marginal band; in the left the corresponding band is more distinct, observable as a low sharp ridge. Hinge-line long, straight, impressed within a flaring U-shaped furrow in the dorsum; ordinarily the hinge contact is slightly up the left slope of the furrow, so that the bottom of the furrow is just within the right valve. Surface smooth.

Average measurements of six specimens: length 1.02 mm.; height 0.6 mm.; thickness 0.55 mm.

K. incarinata lacks the strong ventro-lateral ridges characteristic of *K. naviculata* Delo, the only other species of *Kellettella* with which the author is familiar.

Localities. Railroad cut at Spergen Hill, Norris, Indiana; and Old Cleveland Quarry, Harrodsburg, Indiana; fairly common.

Types. Holotype, no. M 383; paratypes, no. M 384.

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LOCALITIES

(1) Walsh Quarry, one-half mile northwest of Oolitic, near Bedford, Indiana.
(2) P.M.B. Quarry, one-half mile northeast of Oolitic, near Bedford, Indiana.
(3) Railroad cut at Spergen Hill, Norris, Indiana.
(4) Old Cleveland Quarry, one mile northwest of Harrodsburg, Indiana.

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THE GASTROPODS OF THE ST. LOUIS, MISSOURI, PENNSYLVANIAN OUTLIER: IV. THE PSEUDOMELANIIDAE

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ABSTRACT

This paper deals with two species of Pennsylvanian gastropods, *Meekospira peracuta* (Meek and Worthen) and *Actaeonina minuta* (Stevens). The genus *Meekospira* Ulrich is first described and discussed. In the discussion of *Actaeonina* d'Orbigny it is shown that the genotype is the Carboniferous species, *Chemnitzia carbonaria* de Koninck, and that this species cannot be regarded as an opisthobranch, whatever may have been d'Orbigny's intentions in founding the genus and regardless of the fact that most of the post-Paleozoic species commonly referred to *Actaeonina* are opisthobranchs. *Actaeonina* is redefined on the basis of its genotype and other Carboniferous species properly referable to it.

It is shown that *Meekospira* and *Actaeonina* have many significant characters in common and again have much in common with the genus *Pseudomelania* Pictet and Campiche. It is concluded that the Pseudomelaniidae Fischer is, when purged of its extraneous genera, a valid family and that both *Meekospira* and *Actaeonina* are referable to it.

Additions and corrections to two previous papers of this series are carried in two appendices. Appendix A distributes in the synonymies of the paper on the Subulitidae two species reported from Pennsylvania and inadvertently omitted. Appendix B has to do with the paper on the Pseudozygopleurinae and announces that the subgenus *Pyrgozyga* Knight must be considered a synonym of *Palaeostylus* Mansuy and that the latter must displace *Pseudozygopleura* Knight as the nomenclatorially typical subgenus, relegating the latter to a subordinate position. *Procerithiopsis* Mansuy is also discussed.

Superficially resembling the Subulitidae and often confused with them, are four or five American Pennsylvanian species of gastropods, two of which are abundant at the top of the Labette shale in the St. Louis Pennsylvanian outlier. One of these is *Meekospira peracuta* (Meek and Worthen) and the other is that small species identified by Meek and Worthen, I think correctly, with *Macrocheilus minuta* Stevens and referred by them to the genus *Actaeonina*. These two species and their taxonomic position is the theme of this paper.

GENUS MEEKOSPIRA ULRICH, 1897

The genus *Meekospira* was proposed by Ulrich in 1897 (*1*, p. 1079) seemingly to accommodate an Ordovician species he was then dealing with. Curiously, however, he designated an otherwise undiscussed Pennsylvanian form, *Eulima?* (later *Polyphemopsis*) *peracuta* Meek and Worthen, as the genotype. Among older forms which may or may not properly belong to it, he erroneously included in the new genus *Polyphemopsis nitidula* Meek and Worthen and *P. inornata* Meek and Worthen, from the Illinois Pennsylvanian. The for-

mer has been shown to be a synonym for *Soleniscus* (*Soleniscus*) *typicus* Meek and Worthen and the latter for *Soleniscus* (*Macrochilina*) *regularis* Cox (*2*, pp. 207, 222), representatives of a generic group that it is difficult to regard as more than remotely related to *Meekospira*, in spite of a deceptive superficial similarity.

Meekospira may be described as including high-spired, unornamented and imperforate gastropods, with shallow to moderately deep sutures; whorl profile gently arched to nearly flat; aperture subovate, never effuse below; outer lip thin and without a sinus; columella slightly arcuate and without fold; inductura flatly reflexed against and fused with the columella below, thin on the parietal wall and with its outer edge passing spirally inward so as to be nearly invisible above the columella; nucleus smooth, trochoid and dextral. Genotype by original designation *Eulima? peracuta* Meek and Worthen.

Ulrich regards *Meekospira* as occupying an intermediate position between *Loxonema* Phillips and *Soleniscus* Meek and Worthen. To this I cannot subscribe. Though the form of the spire and the inner lip of *M. peracuta* are broadly similar to those of *Loxonema*, its outer lip shows not the faintest suggestion of a loxonematoid sinus at any ontogenetic stage, the *sine qua non* for approach to that genus. Again, *Soleniscus* is siphonostomate (*2*, p. 192) while *Meekospira* is not. Each seems to belong to an entirely distinct genetic line.

The range of *Meekospira* seems to be from the Ordovician to Permian, though I would exclude from the genus all of the pre-Carboniferous species placed in it by Ulrich, except perhaps *M. subconica* Ulrich and *M. planilateralis* (Foerste).

GENUS ACTAEONINA D'ORBIGNY, 1850

The name *Acteonina*, or more correctly transliterated *Actaeonina*, was proposed by d'Orbigny in his "Prodrôme" in 1850 (*3*, p. 118) with the remark, "Ce sont des *Acteon* sans dents ni plis sur la columelle." This remark constitutes his diagnosis. A single species, *Chemnitzia carbonaria* de Koninck was mentioned in connection with this brief diagnosis, although other species are listed elsewhere in all three volumes of the "Prodrôme."

In view of d'Orbigny's obvious intention to establish the genus for tectibranch gastropods and of the subsequent use of the name for tectibranchs, it is unfortunate that Meek in 1863 (*4*, p. 91) designated *Chemnitzia carbonaria* de Koninck as the genotype, since, as I hope to show, that species cannot be even remotely related to the tectibranchs. It is to be hoped that workers in the tectibranchs will petition the International Commission of Zoological Nomenclature to suspend the rules in this instance so that the name *Actaeonina* may be retained in its widely used sense. In such an event a new name will be needed for the Carboniferous forms, but in the meantime *Actaeonina* must be applied to them and with them removed from the

Tectibranchiata and from the Opisthobranchiata.

Unfortunately, the genotype of *Actaeonina* as chosen by Meek, *Chemnitzia carbonaria* de Koninck, is very imperfectly known, but what seem to be its true characters may be inferred from several lines of evidence. The species was first described and illustrated by de Koninck in 1843 (*5*, p. 469, pl. 22, fig. 9*a–c*, and pl. 41, fig. 15*a–c*) and the description based on three specimens, the holotype from de Koninck's own collections from the Viséan limestone, and two specimens supplied the author by the Baron de Ryckholt from the shales at Tournay. The first specimen, the holotype, was quite imperfect and before receiving the last two specimens de Koninck had already prepared the plate on which the first was to be illustrated. He was originally of the opinion that his first specimen was referable to the Tertiary and Recent genus *Conus*, and not only is it so labeled in the explanation of plates but his illustration itself is restored so as to show a long narrow *Conus*-like aperture (*5*, pl. 22, fig. 9). It must be borne in mind constantly when working with de Koninck's illustrations that many of them, and particularly those dealing with the smaller forms, are most inaccurate. His illustrations frequently represent his concept of the species rather than the specimen itself.

After having received the additional specimens from de Ryckholt, he realized he was not dealing with a species properly referable to *Conus* and later referred it to *Chemnitzia* as then understood. One of the latter specimens he figures on another plate (*5*, pl. 41, fig. 15) and we may begin to learn from them the true character of the genus. For the convenience of the reader, copies of de Koninck's illustrations of both specimens are reproduced on Plate two of this paper as figures 1*a–c*.

The matter is, however, still further complicated by the fact that de Koninck in 1881 (*6*, pp. 68, 69) made of the specimens given him by de Ryckholt a new species, *Scalites fusiformis*, at the same time referring *Chemnitzia carbonaria* to the genus *Scalites*. Thus, the genotype of *Actaeonina* again comes to rest on a single poorly preserved and little known specimen, though there can be little doubt that de Ryckholt's specimens are *generically*, if not specifically, related to *Chemnitzia carbonaria*. Hence we are reasonably safe in using them in connection with the holotype of *C. carbonaria* in forming our concept of the genus *Actaeonina*, nomenclatorially based on *C. carbonaria*.

Indeed, inasmuch as a genus is itself only a concept, it must include in its scope the genotype species and all other species believed to be of the same close phyletic stock.

De Koninck again illustrates the holotype of *C. carbonaria* as *Scalites carbonaria* in 1881 (*6*, pl. 3, fig. 25) but this later illustration, though as poor as the original one, is quite different and only serves to confirm the conclusion arrived at from the original illustration, namely, that neither is reliable as to details and that the species is congeneric with de Ryck-

holt's better preserved specimens now also refigured under the name *Scalites fusiformis* (*6*, pl. 3, figs. 23, 24). De Koninck in his later work of 1881 (*6*, pp. 65–69) describes and figures a number of additional species which he also refers to *Scalites* Conrad, and at the same time he specifically refers *Actaeonina* d'Orbigny to the synonymy of Conrad's genus. There is no doubt that some of de Koninck's shells, especially those specimens with sharply angulated and superiorly flattened whorls do resemble *Scalites*, but as Ulrich has pointed out (*1*, p. 933), the essential characters of that genus are poorly known, though it seemingly stands close to *Raphistoma* Hall. An alliance for our Carboniferous shells with *Raphistoma* seems out of the question since they have no raphistomatoid characters whatever. Hence *Chemnitzia carbonaria* and all congeneric species return properly to *Actaeonina*.

Copies of de Koninck's original figures of *Actaeonina carbonaria* are shown as Plate 28, figures 1*a–c*; figures 2*a,b* on the same plate are copies of Meek's and Worthen's original figures of *Actaeonina minuta* (Stevens) (*7*, pl. 29, fig. 2**a*, 2**b*); figures 3*a–p* are photographs of specimens of the latter species from the St. Louis Pennsylvanian outlier. A brief study is sufficient to carry conviction that the three species figured are congeneric. A study of the other species referred by de Koninck to *Scalites* in his later work (*6*, pp. 65–69), and of *Actaeonina angulifera* (White), originally described as *Macrocheilus* (*8*, p. 160, pl. 12, figs. 3*a–f*) shows species differing from those here refigured only in a more robust form and a wider flattened area on the upper surface of the whorls. *Actaeonina canaliculata* (Hall) (*9*, p. 367, pl. 31, fig. 41), a species originally described from the Spergen limestone as *Bulimella* (=*Bulimorpha*), is an example close in general form to the genotype, *A. carbonaria* and to *A. minuta*.

Though it has become the custom to refer some of these Carboniferous species to genera of the Soleniscinae such as *Macrochilina* and *Bulimorpha* they have no trace of a siphonal fold or notch, and are so classified only because of the shape of the spire or the more or less shouldered whorls. But these characters hardly have specific value in either the Soleniscinae (*2*, p. 185, p. 195) or in the genus under consideration.

Actaeonina usually displays a shouldered, or angulated whorl with a more or less flattened upper surface, yet White shows very marked individual variations in this character in *A. angulifera* (*8*, p. 161) and the many specimens of *A. minuta* in my collections show completely intergrading variations from those with a narrow but angular shoulder to others showing shallow sutures and adpressed whorls with no angulation or flattened area at all. As a matter of fact, the angulation and flattening in any specimen of the two American Pennsylvanian species, at least, appears at a variable but relatively late ontogenetic stage. In some examples of *A. minuta* they simply do not appear at all.

Diagnosis of ACTAEONINA. Low to moderately high-spired, unornamented and imperforate gastropods with shallow to deep sutures and with a marked tendency to develop at relatively late ontogenetic stages a subangular shoulder with a flattened upper surface on the whorls; aperture subovate to sublanceolate, never effuse below; outer lip thin and without a sinus; columella slightly arcuate and without folds; inductura thin and inconspicuous, flatly reflexed against and fused with the columella below, passing out of sight on the parietal wall; nucleus smooth, trochoid and dextral; shell rather thick, impunctate and with very fine growth lines. Genotype, by subsequent designation, *Chemnitzia carbonaria* de Koninck.

There seem to be no pre-Carboniferous species referable to *Actaeonina*. The upper limit of its range must for the present remain undetermined. A detailed study of the post-Carboniferous species that might possibly be included in it would carry this work too far afield and would of necessity be based on the literature alone. It may safely be asserted that most of the post-Carboniferous species commonly referred to it are true opisthobranchs.

THE FAMILY RELATIONSHIP OF MEEKOSPIRA AND ACTAEONINA

Meekospira was placed in the Loxonomatidae by Ulrich (*1*, p. 1079) and by Koken and Perner (*10*, p. 250). Girty places it in the Pyramidellidae, though with reservations (*1*, p. 181) and Cossmann in the Subulitidae (*12*, p. 112). None of the several editions of Zittel's *Textbook of Paleontology* mention it at all. It seems difficult to reconcile the simple nonsinuate outer lip of *Meekospira* with the Loxonematidae, its complete lack of siphonostomate characters with the Subulitidae, or its normal, smooth, dextrally coiled nucleus with the true Pyramidellidae.

The genus *Actaeonina*, based as it has been on a definition, on a concept dissociated from its type species, has naturally been placed where that concept and definition would put it, in the tectibranch family Actaeonidae. And indeed that is where it should be on the basis of the characters of the great majority of post-Paleozoic species referred to it. Nevertheless, the generic name must follow the type species, and there is nothing in the significant characters of *Actaeonina carbonaria*, and even less in those of some of the other certainly congeneric but more robust Carboniferous species, to lead one to consider them Paleozoic tectibranchs. These forms comprise the only evidence of the existence of that aberrant group in the Paleozoic. True, the general contours of *A. carbonaria* suggest the Actaeonidae, but general contours are a most unsafe guide, and those of other congeneric species seem to deny such an association as emphatically. If *A. carbonaria* had an heterostrophic nucleus or punctae, or both, one would feel safe, even without any evidence from the soft parts, in considering it to be a tectibranch. As it has neither, and partic-

ularly as there seem to be valid reasons for placing it with a prosobranch family, to regard it as an opisthobranch seems entirely unwarranted. Unfortunately, the name can then no longer be applied to "des *Acteon* sans dents ni plis sur la columelle."

Actaeonina, as here redefined, and *Meekospira* seem to have much in common, particularly as to their apertural characters. Both have the simple, somewhat arcuate and flatly reflexed inner lip, moderately elongate aperture and thin, nearly straight outer lip. In *Meekospira* the spire is high and the whorls without shoulders, while in *Actaeonina* there is a marked tendency toward a sharply angular shouldering of the whorls at later ontogenetic stages, finding in some species almost exaggerated expression. In examples of others it is completely suppressed. No species of either genus has any trace of ornamentation other than very fine growth-lines. Both of them also seem to have much in common with the post-Paleozoic genus *Pseudomelania* Pictet and Campiche. This is true to such a degree in the case of *Meekospira* that one is forced to look to rather inconspicuous characters to differentiate it from *Pseudomelania*. These characters are the more extensively developed inductura (*2*, p. 180) of *Pseudomelania*, which may be seen covering the parietal wall a little way outside of the aperture, and the seemingly distinctive manner of closing off the abandoned earlier whorls in *Meekospira*.

FAMILY PSEUDOMELANIIDAE FISCHER, 1887

The Pseudomelaniidae, as conceived by Fischer, form almost as heterogeneous an assemblage as the Pyramidellidae, as currently used by paleontologists.

Zittel and the subsequent editors of his well known textbook have seen fit to merge the Pseudomelaniidae as a synonym with the Pyramidellidae. They have thrown into the latter *Pseudomelania*, along with an heterogeneous assemblage of Paleozoic to Recent genera, only a few of which can be regarded as having the remotest connection to the true Pyramidellids, or with each other. The

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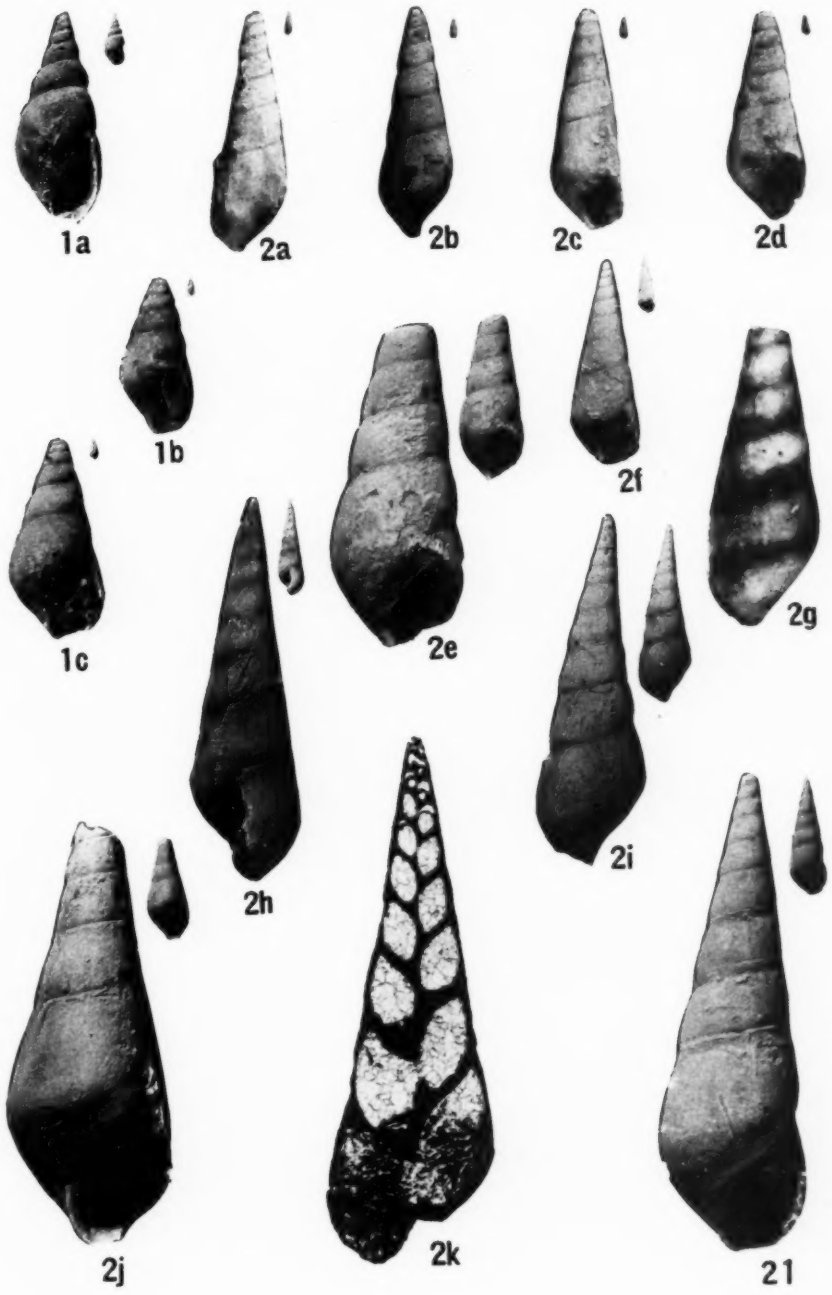
EXPLANATION OF PLATE 27

FIGS. 1*a–c*—*Meekospira sp.* All specimens from the St. Louis outlier. *a*, The largest specimen; probably immature, ×4. *b*, *c*, Two juveniles, ×10. These may be compared with the juveniles of *M. peracuta*, figures 2*a–d*.

2*a–b*—*Meekospira peracuta* (Meek and Worthen). All specimens except 2*j* from the St. Louis outlier. *a–d*, Four juveniles, ×10. *e*, The largest specimen in my collections, ×2. *f*, A specimen, about one-sixth grown, with unbroken apex, ×4. *g*, A specimen illustrating the color-pattern shown by many examples, approx. ×4. *h*, A specimen about one-quarter grown, ×4. The matrix extending beyond the edge of the unusually well preserved outer lip has been slightly darkened. *i*, A specimen about two-thirds grown, ×2. *j*, A specimen about one-third grown, from the "cap-rock of No. 8 coal," Sangamon County, Illinois. This is almost certainly the same bed and the same general area from which Meek and Worthen derived some of their specimens. *k*, Thin-section of a specimen about one-third grown, enlarged. Note the peculiar method of closing off the partially abandoned earlier whorls. *l*, The cyrioplesiotype, an example about one-third grown, ×4.



Knight—Pennsylvanian Gastropods

Pseudomelaniidae, purged of its extraneous genera and limited to the few of its originally contained genera that group themselves naturally about *Pseudomelania*, seem a perfectly valid family and I do not hesitate to place *Meekospira* and *Actaeonina* among them. At first sight the tendency toward developing shouldered whorls displayed by *Actaeonina* might seem to exclude that genus, but a study of Pictet and Campiche's three genosyntypes[1] (*13*, p. 266 ff., pl. 70, figs. 1–8) shows that the same tendency is also present in *Pseudomelania*.

The Pseudomelaniidae may be described as a family of unornamented and typically high-spired, straight-sided, imperforate gastropods, with simple apertures that are angular posteriorly and rounded anteriorly, with a thin, non-sinuate outer lip, an uninterrupted anterior lip and an arcuate columella without folds. The inner lip and parietal wall are covered with a thin inductura. In some genera the whorls have a tendency to develop shoulders which when carried to extremes result in relatively low-spired species with wide, flat upper whorl surfaces. The nucleus is a simple unornamented spire.

[1] I have been unable to find if one of these three has been designated the genotype, but as they are all certainly congeneric, if not more closely related, it is not a matter of great importance. Cossman has designated a species not mentioned by Pictet and Campiche as a neogenotype (*12*, p. 83) following Fischer's selection of the same species (*13*, p. 697) as an example (not a type). His action in so doing, of course, has no standing.

DESCRIPTION OF SPECIES

Family PSEUDOMELANIIDAE Fischer, 1887

Genus MEEKOSPIRA Ulrich, 1897

MEEKOSPIRA PERACUTA (Meek and Worthen)
Plate 27, figures 2*a–l*

Eulima? peracuta MEEK AND WORTHEN, *1860*, Phila. Acad. Nat. Sci. Proc. p. 466. Pennsylvanian, Illinois.

Polyphemopsis peracuta (Meek and Worthen), MEEK AND WORTHEN, *1861*, Phila. Acad. Nat. Sci. Proc. p. 148; *1866*, Ills. Geol. Survey, vol. 2, p. 375, pl. 31, figs. 7*a*, *b*.—WHITE, *1884*, Ind. Dept. Geol. and Nat.

Measurements of Meekospira peracuta

	A	B	C	D	E	F
Number of whorls	14[a]	17[b]	15[a]	13[d]	10	14[e]
Height	17.0 mm.[a]	31 mm.[b,c]	23.8 mm.[a]	13 mm.[d]	6.75 mm.	17.35
Width	4.9 mm.	9 mm.	6.75 mm.	4 mm.	2.25 mm.	5.6 mm.
Ratio of height to width	3.5	3.46	3.55	3.21	3.0	3.1
Ratio of height to body whorl to total	.43	.43	.48	.44	.48	.49
Pleural angle	21°	21°	19½°	20°	22°	22½°[f] 28½°

A. The cyrioplesiotype (pl. 27, fig. 2*l*). A rather perfect example, about one-third maximum size.
B. A plesiotype (pl. 27, fig. 2*e*). My largest specimen, about three quarters maximum size.
C. A plesiotype (pl. 27, fig. 2*i*). A rather large specimen, about two-thirds maximum size.
D. A plesiotype (pl. 27, fig. 2*h*). A specimen about one-quarter maximum size.
E. A plesiotype (pl. 27, fig. 2*f*). A small specimen having the earlier whorls intact.
F. A probable topotype (pl. 27, fig. 2*j*). A specimen, a little over one-third maximum size.

[a] Estimated on the assumption that four apical whorls are missing.
[b] Estimated on the assumption that twelve apical whorls are missing.
[c] Allows 1 mm. for broken anterior lip.
[d] Estimated on the assumption that two apical whorls are missing.
[e] Estimated on the assumption that nine apical whorls are missing.
[f] The smaller angle was measured on the upper whorls of the specimen, and the larger on the lower whorls.

Hist., 13th Rept., p. 163, pl. 32, figs. 9, 10. Pennsylvanian, Illinois.

Polyphemopsis nitidula (Meek and Worthen), WHITE, *1882*, Ind. Dept. Geol. & Nat. Hist., 11th Rept., p. 370, pl. 42, figs. 7, 8; *1884, Loc. cit.*, 13th Rept., p. 163, pl. 27, figs, 7, 8. Pennsylvanian, Vermillion County, Indiana.

Meekospira peracuta (Meek and Worthen), ULRICH, *1897*, Geol. of Minnesota, Final Rept., vol. 3, pt. 2, p. 1079, Pennsylvanian, Illinois.

Meekospira peracuta choctawensis (Girty), PLUMMER AND MOORE, *1921*, Univ. of Texas, Bull. 2132, pl. 14, figs. 3, 3*a*, (not pl. 22, figs. 6, 7) Mineral Wells formation, Pennsylvanian, Mineral Wells, Texas.

Acutely and narrowly subconical; sides of spire straight or concave; whorl profile very gently rounded, almost flat in some specimens and slightly pendant; sutures shallow to very shallow; base somewhat flatly rounded; columella arcuate; inductura flatly reflexed on the columellar lip, thin on the parietal wall and passing out of sight within the aperture; outer lip thin, straight, without sinuosity; aperture somewhat lengthened subovate, rounded below and angular above; surface smooth; growth-lines very faint; color pattern consisting of two narrow revolving dark bands, one just below the upper suture and another bisected by the lower suture.

Sections of *M. peracuta* show an interesting method of closing off the earlier whorls which is illustrated in Plate 27, figure 2 *k*. It appears that at some point in the growth of the animal, the long, slender, spirally coiled apical end of the visceral mass vacated the earliest whorls and took up a position in the few next succeeding whorls, close to the juncture of the columella and parietal wall. The empty space occassioned by the failure of the slender visceral mass to fill the whorls of larger calibre was left open, but partitioned off by the secretion of shelly matter over the soft parts, this new shelly material forming a more slender, spiral shell lying within the partially abandoned whorls. It is not known whether this peculiar method of partially abandoning and closing off the upper whorls is confined to this species or whether it should be regarded as a generic character.

Meek's and Worthen's original specimens of *M. peracuta* are cited in the original publication from Jacksburgh, St. Clair County, and near Springfield, Illinois. When the description was republished with figures by the Illinois Survey the localities were given as near Urbana (now known as Freeburgh), St. Clair County, Illinois, and again near Springfield. In Worthen's report on the Geology of St. Clair County a section is given of the Pennsylvanian beds exposed on "Jack's run, about half a mile east of Urbana" which includes a bed "filled with marine shells belonging to the genera *Bellerophon*, *Pleurotomaria*, *Polyphemopsis* and *Nautilus*" (*15*, p. 303). At the present time I have not succeeded in finding Jacksburgh in any atlas nor in the *Postal Guide*, and it seems logical from the evidence given above to conclude that Jacksburgh was an earlier name for Urbana near Jack's Creek, where gastropods were so abundant, just as the name Urbana is known to have preceded Freeburgh in St. Clair County. If this conclusion is correct, the sources of Meek's and Worthen's original specimens

were from Jack's Run near Freeburgh, St. Clair County, and from near Springfield, Sangamon County, Illinois. Although I have not visited the Freeburgh locality it seems reasonably certain from Worthen's sections that the gastropod horizon there is the same or nearly the same as ours. The specimens here figured from Meek's gastropod bed in Sangamon County, also believed to come from about the same horizon, were kindly given me by Mr. L. G. Henbest, of the Illinois Survey. Thus, aside from the close correspondence with Meek's and Worthen's descriptions and figures shown by my specimens in everything but size, there is additional strong stratigraphic evidence to confirm the identification.

Meek and Worthen give the length of their figured specimen as 1.67 inches (42 mm.). The largest of my many specimens measures approximately 31 mm., while the great majority are very much smaller. This seeming discrepancy in size is, however, not at all surprising in the light of the studies on the matter of size reported in a previous paper (*2*, pp. 47–198) of this series.

Girty in 1915 proposed the name *M. peracuta choctawensis* for what he considered a smaller variety of this species with a wider pleural angle. I cannot but regard Girty's variety as a valid species, *M. choctawensis* Girty, characterized by a wide pleural angle but not by smaller size. It is true that Girty's figured specimens are smaller than Meek's and Worthen's figured specimen, but the latter is an unusually large example and Girty's figured specimens are larger and more robust in every way than the great majority of specimens of *M. peracuta*. Furthermore, large, robust Meekospiras with the wide pleural angle of *M. choctawensis* are common in collections from the upper half of the Pennsylvanian.

Though the evidence is not all in hand, it seems that *M. peracuta* is confined to the lower and *M. choctawensis* to higher parts of the American Pennsylvanian, the division between them falling somewhere in the equivalents of the Pleasanton formation of Missouri. The pleural angle of the earlier and typically smaller species lies close to 21° while that of the later and larger one lies close to 28°.

What appears to be a third species is associated with *M. peracuta* in the St. Louis area, but as it is known from only a few specimens, most of them obviously juveniles, it will be only tentatively described and will not be given a name.

I have 391 specimens of *M. peracuta*, all from the top of the Labette shale. Three of these came from Locality 6 and the rest from Locality 43. Of the latter, 159 were from Zone R, 82 from Zone G, with 147 unallocated as between those two zones. Of the total number of specimens, 81 measure over 1 cm. in length, while 307 are smaller. Cyrioplesiotype, Yale Peabody Museum, No. 13751.

MEEKOSPIRA sp.
Plate 27, figures 1*a–c*

The five specimens here considered belong quite certainly to the genus

Meekospira and seemingly are representatives of an undescribed species. Yet there are so few specimens, four of them quite certainly juveniles and the largest seemingly quite immature, that I hesitate to describe or assign them a name for fear that mature specimens may later be found and fail of recognition. In general the founding of species on one or a few juvenile specimens, however distinctive, seems an unwise procedure. The occurence of these specimens in the top of the Labette shale at Locality 43 is worthy of mention.

Measurements of Meekospira sp.

	A	B	C
Number of whorls	9	6	5
Height	7.1 mm.	2.75	2.1
Width	2.9 mm.	1.23 mm.	.98 mm.
Ratio of height to width	2.45	2.24	2.15
Ratio of height of body whorl to total	.63	.66	.67
Pleural angle	35°	34°	33.5°

A. The largest specimen (pl. 27, fig. 1*a*), possibly a quite young individual.
B and C. Two juveniles (pl. 27, figs 1*c* and 1*b*) respectively.

This form seems to differ from both *M. peracuta* and *M. choctawensis* in having a wider pleural angle than either, and in the possession of deeper sutures. Specimen, Yale Peabody Museum, No. 13752.

Genus ACTAEONINA d'Orbigny, 1850, emend. Knight

ACTAEONINA MINUTA (Stevens)

Plate 28, figures 2*a–b*, 3*a–p*

Loxonema minuta STEVENS, *1858*, Am. Jour. Sci., (2), vol. 25, p. 260, roof of Danville coal and upper shales of the Pennsylvanian, Sangamon Co., Illinois.

Actaeonina minuta (Stevens), MEEK AND WORTHEN, *1873*, Ills. Geol. Survey, vol. 5, p. 594, pl. 29, fig. 2**a*, 2**b*; roof of Danville coal, Pennsylvanian, Danville, Illinois.

Macrichilina? *danvillensis* GIRTY, *1915*, Mo. Bureau Geol. and Mines, 2nd ser., vol. 13, p. 363. General discussion, not *Bulimorpha minuta* (Stevens) Girty.—WARTHIN, *1930*,

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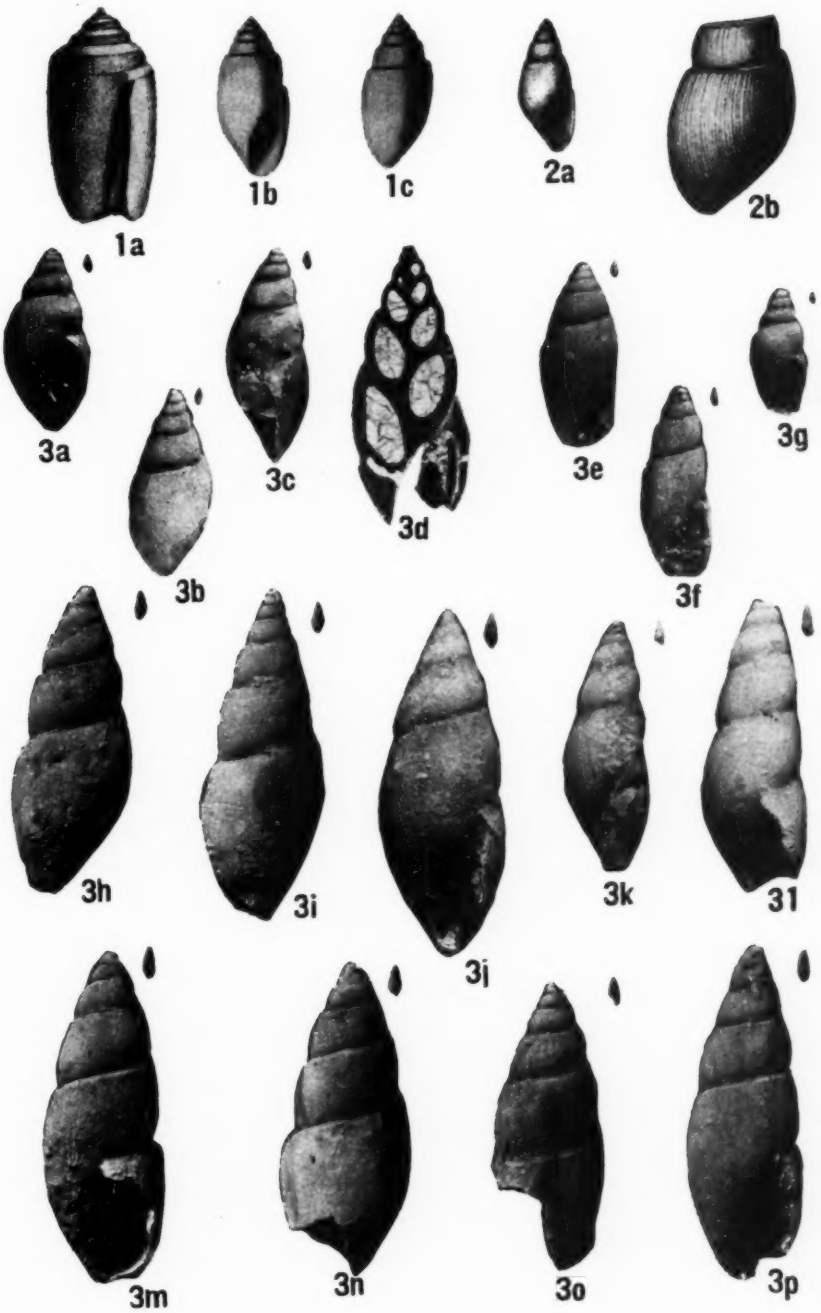
EXPLANATION OF PLATE 28

FIGS. 1*a–c*—*Chemnitzia carbonaria* de Koninck. Reproductions of the original figures. *a*, The first specimen and holotype (*5*, pl. 22, fig. 9), approx. ×4. A later illustration of this same specimen (*6*, pl. 3, fig. 25) shows it to be much more like the specimens shown here as fig. 16 than one might have supposed. *b*, *c*, A specimen originally referred to this species (*5*, p. 469, pl. 41, fig. 15) but later (*6*, p. 69) the basis for a new species, *Scalites fusiformis* de Kon., approx. ×3. I am inclined to consider it as probably identical and certainly as congeneric with the first specimen. This is reproduced here to supplement the inaccurately drawn figure of the small and imperfect holotype. *Chemnitzia carbonaria* is the genotype of *Actaeonina* d'Orbigny.

2*a*, *b*—*Actaeonina minuta* (Stevens) Meek and Worthen. Reproductions of Meek's and Worthen's topotype specimens of Stevens' species. *a*, Apertural view, approx. ×4. *b*, Dorsal view of last two whorls, approx. ×10.

3*a–p*—*Actaeonina minuta* (Stevens) Specimens from the St. Louis outlier, all ×10. *a*, *b*, *c*, and *e*, Young examples one-third to one-half grown. *d*, Columellar section of mature example. *h*, A mature example with shoulder first appearing on the fifth whorl. *i*, A mature example with shoulder first appearing on the third whorl. *j*, A mature robust example, the cyrioplesiotype, with no shouldering at any stage. *k*, A two-thirds grown, slender example with no shouldering. *l*, A very slender, mature example with no shouldering to its whorls. *m*, A mature example with only the sixth and seventh whorls shouldered. *n*, *o*, and *p*. Mature examples with shouldering appearing first on the fourth whorl. *f*, *g*,



Knight—Pennsylvanian Gastropods

Okla. Geol. Survey, Bull. 53, p. 47, pl. 7, fig. 11. Holdenville formation, Pennsylvanian, Oklahoma.

Bulimorpha minuta (Stevens), WARTHIN, *1930*, Okla. Geol. Survey, Bull. 53, p. 48, pl. 7, fig. 12; Holdenville formation, Pennsylvanian, Oklahoma.

Bulimorpha meeki SAYRE, *1931*, State Geol. Survey of Kansas, Bull. 17 p. 146, pl. 16, fig. 6. Drum limestone, Pennsylvanian, Turner and Independence, Kansas.

Bulimorpha (?) *turnerensis* SAYRE, *1931, Loc. cit.*, p. 147, pl. 16, fig. 7. Drum limestone, Pennsylvanian, Turner, Kansas.

Small; fusiform; sides of spire convex; whorl profile gently arched, with or without an angular shoulder with a narrow, flattened upper surface; sutures shallow to rather deep; base narrowly sub-conical; columella arcuate; inductura flatly, though inconspicuously, reflexed on the columella lip, thin on the parietal wall and passing out of sight within the aperture; outer lip thin nearly straight and without sinuosity; aperture somewhat lengthened sub-ovate, rounded below, angular to sub-angular above; surface smooth; growth lines faint; traces of coloration preserved, but insufficient to determine pattern, if any.

As will be seen from the synonymy, from the above description, and from the specimens figured, this species is an exceedingly variable one as here conceived. The variations are in the general contours, and more notably in the degree of expression given the sub-angular shouldering of the whorls. The two vary independently and result in end products which, if taken alone, might be considered specifically, if not generically, distinct. Yet among my some four hundred specimens there seems to be no sharp division. In the nepionic and early neanic stages of all examples the whorl profile shows no angular shouldering. The shoulder may make its appearance as early as the third whorl, in what might be considered a late neanic stage; it may appear for the first time on any subsequent whorl; or it may fail to make its appearance altogether.

This individual variability seems to be the reason for some, at least, of the confusion that has existed relative to this species. Girty, for in-

Measurements of Actaeonina minuta

	A	B	C	D	E
Number of whorls	7	7[a]	7	7	7[a]
Height	4.6 mm.	4.4 mm.	4.5 mm.	4.3 mm.	4.1 mm.
Width	1.65 mm.	1.6 mm.	1.65 mm.	1.70 mm.	1.4 mm.
Ratio of height to width	2.78	2.75	2.78	2.53	2.90
Ratio of height of body whorl to total	.69	.64	.62	.68	.59
Pleural angle, neanic	49°	52°	42°	52°	42°
Pleural angle, ephebic	22°	19°	27°	24°	20°

[a] Estimated on the assumption that one apical whorl is missing.

A. The cyrioplesiotype (pl. 28, fig. 3*j*). An apparently mature example with no angula shouldering to its whorls.

B. A plesiotype (pl. 28, fig. 3*m*). An example, much like the cyrioplesiotype, but with angular shoulders on the sixth and seventh whorls.

C. A plesiotype (pl. 28, fig. 3*i*). A rather slender example, with the angular shoulder appearing on the third whorl.

D. A plesiotype (pl. 28, fig. 3*n*). A rather robust example, with the angular shoulder appearing on the fourth whorl.

E. A plesiotype (pl. 28, fig. 3*l*). A very slender example with no angular shouldering to its whorls.

stance, though recognizing Meek's superior advantages for making a correct identification of Stevens' species (*16*, p. 363), was compelled to hold that Meek was in error when he made such an identification, since he figured a specimen showing a well developed angular shoulder on its whorls, whereas Stevens' description mentioned no such character. A further discrepancy was thought to consist in the comparitive slenderness of Stevens' specimens. While I have no specimen of quite the slenderness indicated by Stevens, a number approach it. Furthermore, I am very skeptical of the accuracy of Stevens' measurements. They are in round figures (0.2 and 0.005 inch) and it seems very unlikely that on such a small object they have any more significance than very rough approximations, too rough to use in a study of ratios. On the other hand, as Girty points, out, Meek was a contemporary of Stevens and is known to have handled specimens of gastropods from Stevens' locality (the roof of the Danville coal at Danville, Illinois) sent to James Hall by Stevens while Meek was in Hall's employ.

The specimen identified and figured by Meek as *Actaeonina minuta* (Stevens) was from Stevens' horizon and locality. Indeed, it may well have been a paratype or metatype furnished by Stevens himself.

The great variability in the species in respect to the two characters which led Girty to conclude that Meek had figured a misidentified specimen, leads me to believe that Stevens' original description was based on a slender individual variant with unshouldered whorls, while Meek figured one at the other extreme of the series. It seems quite possible that the variability in the species was also noted by Meek and that he intended to discuss it but was prevented from doing so by the illness which interfered with or entirely prevented his work on the text, but not the plates of the volume in which the species is figured (*7*, prefatory note, p. 322). It is noteworthy in this connection that most of the Danville species figured in that volume, whether Meek's own or Stevens', are, contrary to Meek's usual practice, without descriptions or discussions.

I have cited in the synonymy of *A. minuta*, *Bulimorpha meeki* Sayre (a stillborn synonym of *Macrochilina? danvillensis* Girty), and somewhat doubtfully, *B. turnerensis* Sayre. These two seem to represent extreme individual variants of *A. minuta*. My hesitation in including *B. turnerensis* is caused by Sayre's vagueness in describing the columellar lip of his species and the indistinctness with which the feature is shown on his figure. There is a vague suggestion of a siphonal notch in the figure, the possession of which would place the species in one of the subgenera of *Soleniscus*.

I have also cited two specimens figured by Warthin, one, a slender, shouldered variant identified as *Macrochilina danvillensis* Girty and the other, a more robust specimen, apparently without shouldered whorls, as *Bulimorpha minuta* (Stevens) Girty. It is very much to be regretted

that Warthin, in his otherwise excellent contribution (*18*), should have attempted the identification and even the description of some new species of gastropods based on juvenile, in some cases even nepionic, individuals. While in some instances, as in the present species, their relations can be recognized, some of the new "species" cannot be identified with their adult form. As an example, Doctor Warthin was good enough to send me for examination the holotype of *Loxonema zygopleuroides* Warthin. It is the nepionic shell, the nucleus merely, of some even generically undeterminable species of the Pseudozygopleurinae.

I have 401 specimens assigned to this species, all from Zone R at the top of the Labette shale at Locality 43. Of this number some thirty-five show no shouldering to their whorls. Cyrioplesiotype, Yale Peabody Museum, No. 13753.

REGISTER OF LOCALITIES

This is the fourth paper of a series dealing with the gastropods of the St. Louis Pennsylvanian outlier. The reader is referred to previous papers for such matters as the stratigraphic section, register of localities (*2*, p. 227), acknowledgments and other matters of a general nature. The figured specimens of the species are deposited at Peabody Museum of Natural History at Yale University. Other plesiotype specimens are at the U. S. National Museum at Washington, Washington University at St. Louis and the Musée Royale d'Histoire Naturelle at Bruxelles, Belgium.

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APPENDIX A

ADDITION TO PREVIOUS PAPER, ON THE SUBULITIDAE (2)

Although Raymond's paper on the faunas of the Allegheny and Conemaugh series in Pennsylvania was at hand during the preparation of the previous paper of this series (*2*), two species figured by Raymond were inadvertently omitted from the synonymies. In the synonymy of *Soleniscus* (*Macrochilina*) *primogenius* (Conrad) should appear:

Sphaerodoma primogenia (Conrad), RAYMOND, *1910*, Carnegie Museum, (Pittsburgh), Annals, vol. 7, p. 26, fig. 5; Brush Creek limestone, Conemaugh series, Pennsylvanian, Donohoe, Pa.

In the synonymy of *Soleniscus* (*Macrochilina*) *irregularis* (Cox) should appear:

Soleniscus fusiformis (Hall), RAYMOND, *1910*, *Loc. cit.*, plate 24, fig. 7; Vanport limestone, Allegheny series, Pennsylvanian, at New Port, Pa.

Raymond's figure of *S.* (*M.*) *primogenius* is of particular interest as it is from Conrad's original horizon, close to the type locality for the species.

APPENDIX B

CORRECTION TO PREVIOUS PAPER, ON THE PSEUDOZYGOPLEURINAE (*17*)

I have only recently seen for the first time Mansuy's magnificent works on the late Paleozoic faunas of Indo-China and find what seems to be the subgenus *Pyrgozyga* Knight described as *Palaeostylus* (*19*, p. 48) which, of course, takes precedence. The genotype of Mansuy's genus, as designated by Cossmann (*20*, p. 323), *Palaeostylus pupoides* Mansuy, seems to have all the adult characters of *Pyrgozyga*, though Mansuy neither describes nor illustrates its nepionic characters. There seems to be little room for doubt, however, that *Pyrgozyga* must be regarded as a synonym of *Palaeostylus*. This equivalence being accepted, *Palaeostylus*, the first described of a group of subgenera, takes its place as the nomenclatorially typical subgenus and thus displaces *Pseudozygopleura* Knight from that position to the rank of a subordinate subgenus.

Mansuy also describes in the same work (*19*, p. 50) another genus *Procerithiopsis* that may eventually be found to conflict with some other subgenus previously referred to the Pseudozygopleurinae, though Mansuy describes as an essential character a well developed columellar fold. Such a character would of course remove it widely from the Pseudozygopleurinae if it actually exists. Cossmann, however, (*20*, p. 322) is of the opinion that Mansuy was misled by a piece of foreign matter in attributing a columellar fold to *Procerithiopsis*. In any case, a restudy of the type specimens of *P. ambiguus* Mansuy, the genotype, must be awaited to determine definitely not only this point, but others of its characters that would properly place it among the subgenera of *Palaeostylus* (=*Pseudozygopleura*).

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A USEFUL FORAMINIFERA HORIZON IN THE ALBERTA SHALE OF SOUTHERN ALBERTA

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Means of making accurate correlations for structural determination in drilling for oil and gas in southern Alberta are few. The top of the lower Milk River (Virgelle) has commonly been used as a horizon-marker in wells and test holes. The surface of this formation, however, may not be regular and opinions may differ as to where the contact should be placed in a series of well samples.

A study of foraminifera in well samples shows that these fossils can be used for making accurate correlations in this region. Foraminifera are known to occur in all the marine Upper Cretaceous formations of southern Alberta. These are the Bearpaw, Pakowki, and Alberta[2] shales. As most of the wells start below the Bearpaw, the fauna of this formation is of little significance. The fauna of the Pakowki is inadequate for correlation purposes. The Alberta shale, however, contains numerous foraminifera at several horizons, and with care these can be used for making accurate correlations.

The species described in this paper are found in a zone about 200 feet thick, the upper limit of which is about 300 feet below the top of the Alberta shale. While there are at least twenty species which occur in this zone, only eight are described here. These eight were chosen because they occur in all the wells and are easily recognized. The uppermost occurrence of two species at a horizon about 420 feet below the top of the Alberta shale can be used as a datum plane for correlation purposes and the other species may be used to check the results. The two species thus used are *Clavulina* sp. and *Bullopora laevis* (Sollas).

This fauna occurs at least as far north as Lethbridge and as far east as Skiff, Alberta. It has not been observed in material from the Ribstone field or from central Saskatchewan. It is likely that the fauna is confined to southern Alberta and Montana.

[1] Published with the permission of the Director of the Geological Survey of Canada, Ottawa.

[2] The name Alberta shale was given by G. S. Hume (*Geol. Survey Canada*, Summ. Rept. 1929, Pt. B) to a dark shale formation in the foothills which had been called Benton or Colorado. The lower part of this formation is definitely of Colorado age, but the beds near the top contain Montana fossils. The formation, therefore, cannot be properly designated by the old names. C. S. Evans more recently has found that the same thing is true of similar shales in southern Alberta (*Geol. Survey Canada*, Summ. Rept. 1930, Pt. B.).

Acknowledgments are due to the several companies operating in southern Alberta for the permission to publish these results of examination of samples from their wells, to Dr. C. S. Evans of the Geological Survey of Canada who furnished the stratigraphic information and checked the results by means of other data, and to Mr. Arthur Miles who made the illustrations.

Samples from the following wells were examined:

Alberta Pacific Consolidated, Red Coulee No. 1, Sec. 4, T. 1, R. 16, W. 4th M.
Border Oils Company (Diamond Drill core) Sec. 6, T. 1, R. 14, W. 4th M.
Commonwealth Red Coulee No. 1, Sec. 3, T. 1, R. 16, W. 4th M.
Dalco No. 2, Sec. 19, T. 2, R. 17, W.4th M.
Devonshire No. 1, Sec. 10, T. 1, R. 16, W.4th M.
Ko-Top No. 1, Sec. 2, T. 1, R. 17, W.4th M.
Lethalta No. 1, Sec. 33, T. 8, R. 18, W.4th M.
Sax No. 1, Sec. 3, T. 1, R. 16, W.4th M.
Vanalta No. 2, Sec. 4, T. 1, R. 16, W.4th M.

DESCRIPTION OF SPECIES

Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

REOPHAX TEXANA Cushman and Waters
Plate 29, figure 1

Reophax texana CUSHMAN AND WATERS, *1927*, Contr. Cushman Lab. Foram. Res., vol. 2, p. 82, Pl. 10, Fig. 2.

Test free, elongate, a rectilinear series of globular chambers; sutures distinct, depressed; walls arenaceous, of fair-sized grains with a moderate amount of cement; aperture a simple opening at the apertural end of the last formed chamber.

Length about 0.55 mm., width about 0.2 mm.

Occurrence, Upper Cretaceous, Alberta shale, about 330 feet to 450 feet below the top of the formation in southern Alberta. Figured specimen from the Ko-Top well at a depth of 810 feet below the surface. The upper range of this species seems to be about 70 to 100 feet above the *Clavulina* zone.

Care has to be taken not to confuse specimens of *Reophax* with broken *Clavulinas*.

Family LITUOLIDAE

Genus AMMOBACULITES Cushman, 1910

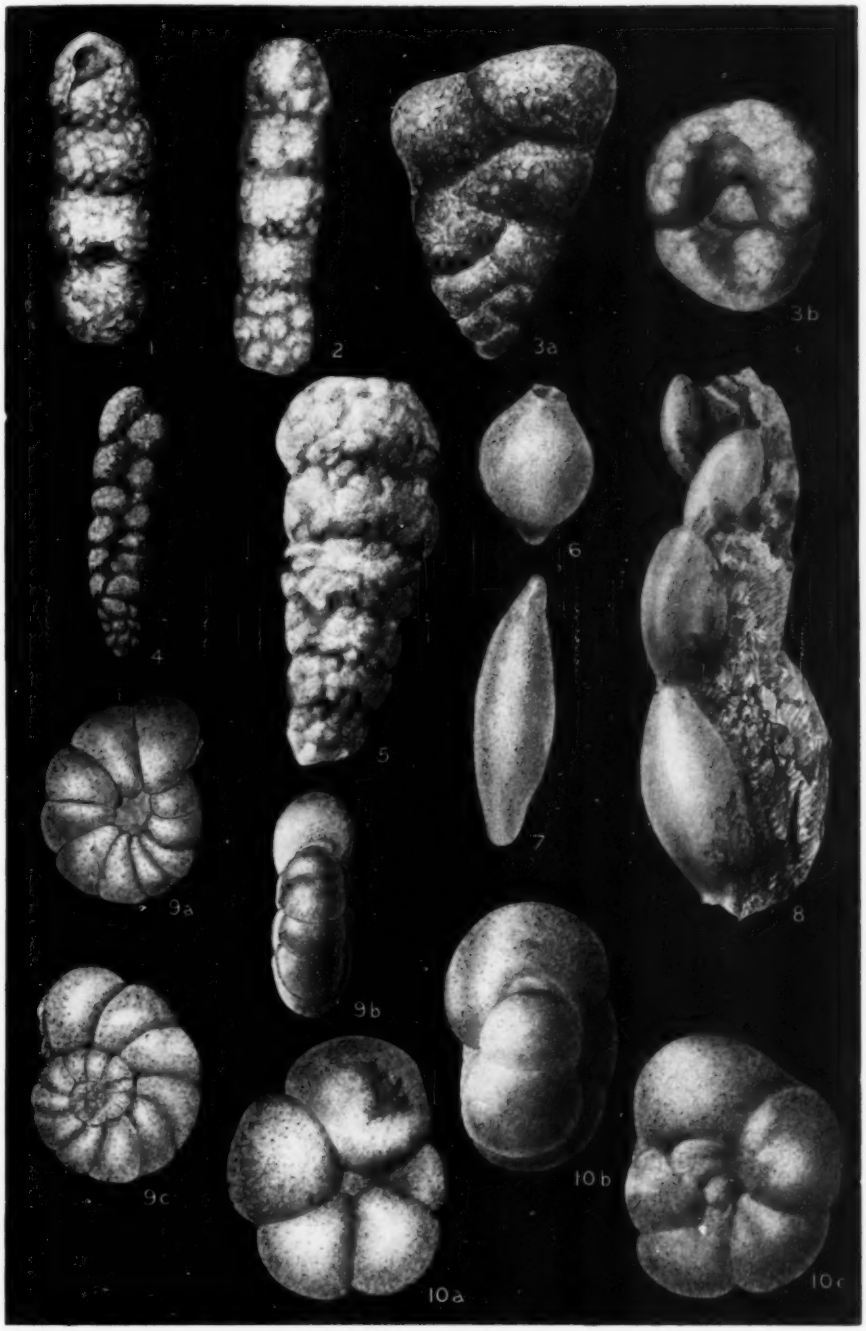
AMMOBACULITES COPROLITHIFORMIS (Schwager)
Plate 29, figure 2

Haplophragmium coprolithiforme SCHWAGER, Beneck's Geogn. pal. Beitrage, vol. 1, *1868*, p. 654, pl. 34, fig. 3.

Test elongate early portion coiled, later uniserial; chambers globular; sutures distinct; walls slightly depressed, arenaceous, of fairly coarse

EXPLANATION OF PLATE 29

FIGS. 1—*Reophax texana* Cushman and Waters, ×77. (No. 6695).
2—*Ammobaculites coprolithiformis* (Schwager), ×77. (No. 6696).
3*a*, *b*—*Gaudryina oxycona* Reuss ×77. *a*, side view; *b*, apertural view. (No. 6771).
4—*Gaudryina filiformis* Bethelin, ×77. (No. 6772).
5—*Clavulina sp?* ×48. (No. 6773).
6–8—*Bullopora laevis* (Sollas), ×48. (Nos. 6774C, 6774B and 6774 A, respectively).
9*a–c*—*Gyroidina depressa* (Alth), ×77. *a*, Ventral view; *b*, dorsal view; *c*, peripheral view. (No. 6775).
10*a–c*—*Anomalina moniliformis* (Reuss) *fide* Franke, ×115. *a*, and *c*, Side views; *b*, apertural view. (No. 6776). All figured specimens in the National Museum of Canada Type Collection. Figures drawn by Mr. Arthur Miles.



Wickenden—Cretaceous Foraminifera

grains and a moderate amount of cement; aperture a simple opening at the end of the last formed chamber.

Length 0.6 mm. to 0.7 mm., width 0.15 mm. to 0.2 mm.

Occurrence, Upper Cretaceous, Alberta shale in southern Alberta, about 340 to 450 feet below the top of the formation. Figured specimens from Border Oils well at 543 feet below the surface.

This species usually appears about 70 feet above the *Clavulina* zone, and becomes very abundant in that zone.

Family VERNEUILINIDAE

Genus GAUDRYINA d'Orbigny, 1839

GAUDRYINA FILIFORMIS Berthelin
Plate 29, figure 4

Gaudryina filiformis BERTHELIN, *1880*, Mém. Soc. Géol. France, 3rd sér. vol. 1, p. 25, pl. 1, figs. 8*a–d*.

Test elongate, early portion triserial; chambers globular; sutures distinct, curved, depressed; walls arenaceous, of fine-grained material with a moderate amount of cement.

Length about 0.48 mm., width about 0.12 mm.

Occurrence, Upper Cretaceous, Alberta shale in Alberta, about 300 feet below the top of the formation. Figured specimen from the Devonshire well No. 1 at a depth of 470 feet below the surface. This species usually first appears about 100 feet above the *Clavulina* zone.

GAUDRYINA OXYCONA Reuss
Plate 29, figures 3*a*, *b*

Gaudryina oxycona REUSS, *1860*, Sitz. k. Ak. Wiss. Wien, vol. 40, p. 229, pl. 12, figs. 3*a*, *b*.

Test somewhat conical, triserial in early portion, later biserial, periphery broad, rounded, width nearly as great as length; chambers subglobular, nearly tabular; sutures distinct, curved, slightly depressed; walls arenaceous, thin, of small grains with much cement; aperture a rounded opening in a re-entrant at the base of the last formed chamber.

Length about 0.41 mm., maximum width about 0.38 mm.

Occurrence, Upper Cretaceous, Alberta shale in southern Alberta, at about 400 to 470 feet below the top of the formation. Figured specimen from the Border Oils wells at 543 feet below the surface.

This species seems to be fairly abundant in all the wells and usually first appears about twenty feet above the *Clavulina* zone. Because of the thinness of the walls, most of the specimens are somewhat crushed. The one figured, while it is not badly distorted, is slightly crushed from the sides. Other specimens were found which were crushed from the ends. The broad flare of the apertural end of this species makes it easily recognized.

Genus CLAVULINA d'Orbigny, 1826

CLAVULINA? sp.
Plate 29, figure 5

Test fairly large, elongate, tapering toward initial end, early portion triserial, later uniserial; chambers subglobular; sutures slightly curved, depressed; walls thick, arenaceous, of fairly coarse grains with much cement; aperture a round opening at the terminal end of the last-formed chamber.

Length 1.8 mm. to 2.5 mm., width 0.22 mm. to 0.5 mm.

Occurrence, Upper Cretaceous, Alberta shale in southern Alberta, about 420 to 530 feet below the top of this formation. Figured specimen from the Ko-Top well at a depth of 820 feet below the surface.

This species marks the most easily recognized and consistent foraminiferal horizon found thus far in the wells of southern Alberta. The thick walls and tapering test make it easy to distinguish from other species which have a uniserial portion. The specimens all seem to be broken at the base and it is difficult to find individuals with a trace of the triserial portion of the test.

Family LAGENIDAE

Genus BULLOPORA Quensted, 1858

BULLOPORA LAEVIS (Sollas)
Plate 29, figures 6–8

Webbina laevis SOLLAS, *1877*, Geol. Mag., 2nd dec., vol. 4, p. 103, pl. 6, figs. 1–3.

Test attached or free, consisting of a series of more or less globular chambers with tubular connection; sutures distinct, depressed; walls calcareous, perforate, smooth or rough, or slightly spinose; aperture simple.

Occurrence, Upper Cretaceous, Alberta shale in southern Alberta. Figured specimens from Alberta shale in the Border Oils well at a depth of 543 feet below the surface. This species is a good guide fossil for a horizon about 420 feet below the top of the Alberta shales in southern Alberta. It was found at this horizon in all the wells examined.

The specimens of this species are usually broken so that all one finds is the individual chambers. These chambers show considerable variety of form some being almost cylindrical while others are nearly spherical. The surface of the walls is also variable in the rounded specimens; it is spinose in some cases whereas in the more elongate forms it is usually smooth. Sollas made two species of these varieties but this does not seem necessary since specimens which grade from one extreme to the other can be found in one sample.

Family ROTALIIDAE

Genus GYROIDINA d'Orbigny, 1826

GYROIDINA DEPRESSA (Alth)
Plate 29, figures 9*a–c*

Rotalina depressa ALTH, *1850*, Haidinger's Naturw. Abhandl. vol. 3, pt. 2, p. 266, pl. 13, fig. 21.

Test coiled, trochoid, last whor almost completely covering the ventral side; both sides somewhat umbilicate; chambers globular, about ten in the last whorl; sutures distinct, depressed, slightly curved; walls calcareous, perforate; aperture a low arch at the base of apertural face of the last formed chamber.

Diameter about 0.38 mm., thickness about 0.18 mm.

Occurrence, Upper Cretaceous, Alberta shale, about 370 feet to 450 feet below the top of the formation. Figured specimen from the Border Oils well at 543 feet below the surface. This species in most cases first appears about 50 feet above the *Clavulina* zone.

Family ANOMALINIDAE

Genus ANOMALINIDAE d'Orbigny, 1826

ANOMALINA MONILIFORMIS?
(Reuss) fide Franke
Plate 29, figures 10*a–c*

Anomalina moniliformis (Reuss) FRANKE, *1928*, Abhandl. Preuss. Geol. Landes., new ser., vol. 3, p. 181, pl. 16, fig. 10.

Test close-coiled, almost completely involute, umbilicate, chambers globular, inflated, five or six to a whorl; sutures, distinct, depressed, radiate; walls calcareous, fairly coarsely perforate; aperture a low arch at the base of the apertural face of the last-formed chamber, extending a little to the dorsal side.

Diameter about 0.45 mm., thickness 0.36 mm.

Occurrence, Upper Cretaceous, Alberta shale in southern Alberta, about 350 to 440 feet below the top of the formation. Figured specimen from the Devonshire well No. 1 at 520 feet below the surface.

This species is easily recognized and is usually found about 60 to 70 feet above the *Clavulina* zone.

PALEONTOLOGICAL NOTES

THE VARIABILITY OF VULVULINA PENNATULA BATSCH

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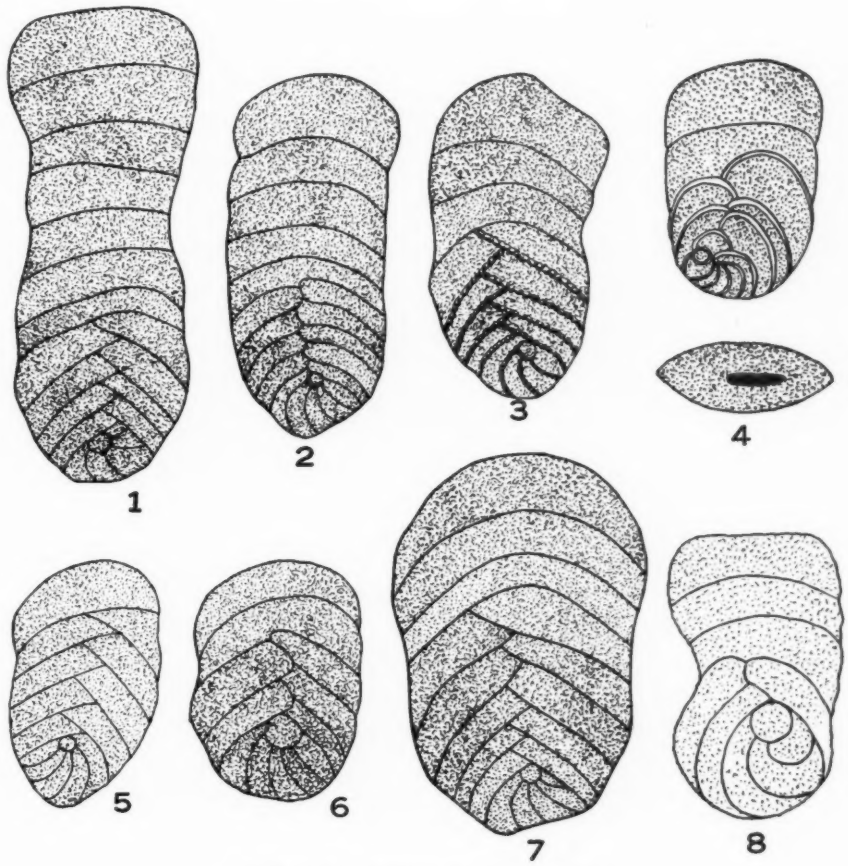
If we do not take into account the first designation of this species as *Orthocerina pupa* Soldani[1] or *Nautilus (orthoceras) pennatula* Batsch[2] which give confused views concerning the position and constitution of the foraminifera, we find the first well characterized form under the name *Vulvulina elegans* d'Orbigny.[3] The genotype of *Vulvulina* is *V. capreolus.* D'Orbigny speaks, it is true, of the form as biserial throughout, but he refers to the illustrations of Soldani which show two uniserial chambers. The character which he especially emphasized is the terminal, elongate, slit-shaped aperture. *V. capreolus* was placed in two genera by Reuss, who first designated it under the name *Grammostomum* (although under this old designation of Ehrenberg were included not only *Vulvulina,* but also *Textularia, Bolivina, Virgulina* and perhaps some of the Polymorphinidae), then later to *Schizophora,* a name applied by Reuss to forms derived from *Textularia* and resembling *Lingulina* in the construction of the later chambers. Based on this last mentioned character we find d'Orbigny in 1826 using the name *Lingulina soldanii* for *V. pennatula.* Misunderstanding the stages in development, Costa in 1857[4] united such forms with *Textularia,* while Schwager, led by the analysis of the structure of the test, used the name *Bigenerina* for these forms in which the early part corresponds to *Textularia* and the later becomes uniserial.

From the fact that *Textularia* represents one stage in diverse forms, Schubert was convinced that these forms were trimorphic in that (as was already seen in the older illustrations of Batsch) the early part of the test shows the chambers spirally arranged, after which occur biserial chambers, and the last-formed portion has the chambers in a uniserial rectilinear series. He calls such forms as those which he had at the time, and which were built up in this manner, *Trigenerina,* taking as a starting point the genus *Spiroplecta* which showed already two stages in this development. The older authors had been correct in their descriptions so far as the instruments which they used were able to reveal the exact analysis of the structure. Having studied material of the Upper and Lower Tertiary the author dealt with the two species *V. capreolus* and *V. pennatula,* which seem to be well distinguished from one another. *V. capreolus* appears to be representative of a more primitive type. The *Textularia*—or better, *Spiroplectammina*—part terminates in a few uniserial chambers. In the study of Oligocene material from Moravia a third form was found, generally fitting into the *V. pennatula* series, and showing a tendency to multiply the uniserial chambers, but being very slender and with a finely agglutinated wall in contradistinction to the appearance of typical *V. pennatula.* I have published this form under the name *Trigenerina folium.*[5] A little later study of Tertiary material from Albania[6] revealed large well developed specimens of *V. pennatula* showing a considerable variability. In that paper one of these forms was figured, and of the others I gave only a description with the measurements of the length and breadth, and the relative proportion of the older part of the test to the younger uniserial portion. This variability seems worthy to be figured, and therefore I am

[1] *Testaceographia,* 1791.
[2] *Conchyliologic des Seesandes,* 1791.
[3] *Ann. Sci. Nat.,* 1826.
[4] *Mem. Accad. Napoli.*
[5] *Naturw Zeitschr. Lotos,* 1922, 70, pp. 47-48; 1924, 72, pp. 112-113.
[6] *Palaeontographica,* vol. 70, 1928.

publishing these statements. These variable forms have been found in the specimens V 32, Strasse nach Vajza (street toward Vajza) 1 and V 63 in the central part of Albania in the vicinity of Valona. The former two are probably of Miocene age, and the latter one is older. The great amount of variability concerns especially the samples of specimen V 32.



Varieties of *Vulvulina pennatula* Batsch.

(1) The longest specimen (2.3 mm. long and 0.9 mm. broad) has a great number of uniserial chambers. The relative proportion of the early stage to the uniserial terminal portion may be stated as 1:2. The spiral portion has been determined only by very strong lighting (fig. 1). The last chamber shows marks of breakage indicating the fact that originally there was a greater number of uniserial chambers which have been broken away.

(2) The second specimen (1.7 mm. long and 0.9 mm. broad) has a distinct spiral portion consisting of the proloculum of six chambers, which is followed by a biserial portion of nine chambers and a uniserial portion of five chambers (fig. 2). The relative proportion of the length of the older part to the uniserial portion is about 1:2, the early portion being a

little longer than in the uniserial portion.

(3) The third specimen (1.5 mm. long and 0.8 mm. broad) has a spiral portion of five chambers including the proloculum, a biserial portion of eight chambers, and a uniserial portion of three (fig. 3). This form is distinguished from other types of this species by the sutures of the earlier portion which are raised into definite ribs which consist of a row of single grains. The relative proportion of the older portion to the uniserial one is 1:1. I have already found a similar form in sediments of Miocene age in the vicinity of Olmütz in Moravia (fig. 4). The spiral early portion shows six chambers; the succeeding biserial portion also has six chambers; and the uniserial development has only two. The spiral and biserial stages have a smooth raised ribs.

(4) A very coarsely agglutinated form (1.2 mm. long and 0.9 mm. broad) has such a coarse surface that the sutures are visible only in the later portion of the test. The spiral portion including the proloculum has six chambers, followed by eight biserial ones and a single uniserial chamber, these last somewhat oblique to the general axis of the test. The relative proportion of the earlier part to the uniserial one is 3½:1 (fig. 5).

(5) Another variety (1.2 mm. long and 0.9 mm. broad) has a well developed spiral portion consisting of six chambers, five in the following biserial part, and the uniserial portion consisting of two chambers. The relative proportion of the earlier part (spiral and biserial) to the uniserial portion is 3:1 (fig. 6).

(6) The extremely broad type (fig. 7) (1.7 mm. long and 1.2 mm. broad), the spiral portion of which it is difficult to distinguish has the greatest expansion in the biserial portion and contains perhaps nine chambers, while the uniserial portion has three. The number of chambers in the earlier portion is perhaps six. The relative proportion of these to the uniserial part is 2:1.

To all these forms from specimen V 32 may be added another from specimen V 63. This specimen (1.4 mm. long and in the later portion 0.9 mm. broad) (fig. 8) was figured in the paper on the Tertiary foraminifera of Albania.[7] The spiral portion is especially well developed, and consists of five chambers, the biserial portion of two, and these followed in turn by three uniserial chambers. In the same collection there was found a very much damaged specimen distinguished by an especially high development of the spiral portion including 5–6 chambers, after which follow four biserial and one uniserial. The test is 1.1 mm. long.

[7] *Palaeontographica*, vol. 70.

DISCUSSION

THE VALUE OF FOSSIL FRAGMENTS

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University of Mysore, Bangalore, India

I have read with great interest, the communication on "The value of Fossil Fragments" by Jerome S. Smiser recently published in your *Journal*.[1] The paper relates to a subject which, I think, is of vital interest to all serious students of paleontology, and I have no doubt that many of the views expressed by the writer will be endorsed by all systematic paleontologists. The author has, however confined his attention only to fragments of macro-fossils and even of these only a few examples are given. I feel that many of the ideas suggested by the writer for proceeding with the identification of fragments of macro-fossils, may easily be extended to the case of micro-fossils also. I should like to take this opportunity of expressing some of my ideas on this subject of the identification and value of fossil fragments—whether macro or micro; and in making these remarks, I chiefly rely on observations made in the highly fossiliferous rocks of the Trichonopoly Cretaceous area, South India.[2]

In the first place it is obvious, as Mr. Smiser has pointed out, that this work of identifying fossil fragments should come only after one "has a thorough understanding of the details of the complete fossil." Even then I think, this work will become easier when one has a very large collection of fragments of all sorts of a particular type of fossil available for study, thus providing probably a series of links, as it were, connecting the complete and entire fossil at one end and the merest fragment at the other. If the person who is making such a collection in the field is the one who is also going to identify them, this collection could be really made more useful; for when one is in the field in the heart of the area where thousands of these fragmentary fossils of a particular type are probably available, mixed up with others which are more or less entire, he will actually see how starting from the complete fossil the material becomes more and more fragmentary, and consequently less and less definite, showing all gradations as it were in the degree of imperfection, till at last he comes to very small and incomplete fragments which he will be still able to recognize as referable to the same type of which he has seen better specimens in the same area. By a judicious collection of fossil fragments from such a locality, the paleontologist can not only make his work of identifying fossil fragments easier but also make his identifications more convincing. Under these circumstances one can make a definite identification of a mere fragment—which if removed from the rest of the collection and placed as such in the hands of an outsider will be probably considered by him as a "dumb fossil." The case becomes slightly different when we are dealing with a collection of fossils of a particular type made up wholly of fragments and wherein complete or anything like complete specimens are entirely wanting; and it may be that even in the area from which this collection is made, it is not possible to get at complete forms. Then it becomes necessary to be able to restore the full form and then proceed with the identification—a task wherein a previous thorough

[1] Vol. 5 No. 3 pp. 293-295.

[2] What is known as the Trichinopoly Cretaceous of South India includes a series of sedimentary rocks, full of fossils so varied and abundant that the area is aptly described as forming a veritable field museum of Cretaceous paleozoology. The Cretaceous rocks of this area can be divided into four stages: (a) Utatur; (b) Trichinopoly; (c) Ariyalur; and (d) Niniyur, ranging in age from Cenomanian to Danian.

knowledge of the detailed structure and organization of that particular group of fossils becomes all the more essential. With a fairly large collection of fragments to rely upon, such work is often possible and this procedure has been resorted to in several cases. We can go a step further in this realm of uncertainty and imagine a case where one is called upon to proceed with the identification of a fossil type when all the material available consists only of a few, and those very poor, fragments. This kind of work must always be left to the "expert" who has probably devoted his lifetime to the study of that particular group, and who by a sort of intuition or instinct, can detect the identity of the merest fragment, belonging to any member of the group in which he has specialized.

Of course it must be remembered that it is not in all groups that this work of identifying fossil fragments could be successfully carried out. In some cases such a work is impossible, for in some groups there are certain parts in the entire fossil which have little or no diagnostic value and unfortunately it is these useless parts that are commonly preserved in the fossil condition. As an example I may mention the fragments of belemnites that occur so plentifully in the shales of the Utatur division of the Trichinopoly Cretaceous area. The whole area of these shales is full of these fragments which can be picked up by cartloads. But all these fossils are fragments of the solid guard, and all that they show is the smooth, cylindrical form, acutely pointed at one end. Beyond saying that all these fragments are referable to the belemnites, no more definite or specific identification is possible. So also the case with the fragments of *Radiolites* so numerously found associated with certain sandstones of the Ariyalur stage. Another interesting example of such fragmentary fossils which are almost dumb is that of the reptilian bones, so commonly found in fragments associated with certain other beds of the Ariyalur stage. Since all that was known some time back about the reptilian remains from the Trichinopoly Cretaceous area was a single tooth discovered by Blanford and identified by Zittel as probably belonging to *Megalosaurus,* it has been the ambition of several investigators to explore this area more thoroughly for other and more informing specimens of these reptilian remains. Though within the last five or six years an intensive exploration has resulted in the discovery of a few complete and definitely recognizable remains such as the vertebra I described some time back (*Proc. Geo. Soc.,* Lon. No. 1169, dated 1 June 1927, p. 103), yet the fact is that when one goes to the area, he will frequently come across quite a large number of fossilized bony fragments scattered all over, but without anything more definite about them. You pick up hundreds of these fragments—they are all bone—but not one of these has the form or appearance that will suggest even an approximate identification. Until the time comes when some method will be developed to make these "dumb" fragments "speak," they are obviously valueless for definite identification.

But on the other hand, it is also possible to cite several examples from local occurrences of fossils, such as those mentioned by Smiser, where certain distinctive characters, such as type of ornamentation, are so uniformly distributed all over the fossil type that a definite identification can be made from even a small fragment. The ammonites, lamellibranchs, and gastropods, so abundant practically all through the Trichinopoly Cretaceous, afford numerous examples of such groups. Particular reference has been made by Smiser to the echinoids from the Texas Cretaceous, the study of which has demonstrated "that nearly all the genera and many of the species can be recognized from small fragments or plates from the test." Another example from this group, which admits of the same kind of treatment and study as Smiser has adopted in the case of *Holaster simplex,* is the form *Stigmatopygus elatus*

which occurs very plentifully in the lower beds of the Ariyalur division. A whole area nearly a half-mile in width and about two miles in length is full of this fossil and specimens of all grades of perfection can be picked out, and the identity of some of the smallest fragments in relation to the entire form is easily seen.

As I have already mentioned above, many of these ideas regarding the identification of fragments of macro-fossils may easily be extended to the case of micro-fossils also. I have recently been engaged in the study of some of the micro-organisms, chiefly foraminifers and radiolarians, from the Trichinopoly Cretaceous rocks. It is my experience, and I daresay it is the same with others who have worked in this field, that a clear knowledge of all the details of the entire form is absolutely necessary before one can attempt the identification of fragments, particularly so when one's material is only in the form of micro-sections. Taking a group like the foraminifers, for instance, we can easily imagine how entirely different genera may present similar looking sections and conversely how one and the same genus may yield entirely different looking sections, all depending upon the direction in which the section is cut with reference to the entire form. In the actual work of identification, also, I have found that several fragmentary sections which appeared at one time to be meaningless and impossible to identify, became perfectly intelligible some time later on when more entire and better preserved forms were recognized. It was then possible to argue backwards, as it were, and say something definite about the fragments previously given up as useless. It is needless for me to go into details and cite actual examples, for I believe I am only recording here what must be the experience of practically every worker in this field.

As Smiser has said in the last sentence of his paper, the main object in writing his note is to stimulate more interest in the study of fossil fragments. It is certainly necessary to do this, especially in view of the growing tendency among some of the mere stratigraphical field geologists to be content with a few complete and well preserved fossils from any area and mercilessly to discard all fragments as not worthy of serious attention.

REVIEWS AND NEW PUBLICATIONS

DUNBAR, CARL O., and CONDRA, G. E., Brachiopoda of the Pennsylvanian System in Nebraska: *Neb. Geol. Survey*, ser. 2, Bull. 5, 377 pp., 44 pls., 1932.

This extremely important contribution to the paleontology of the Pennsylvanian of North America is much more comprehensive than its title implies, for the book is devoted not alone to fossils from Nebraska but is based on extensive collections covering almost all of the northern Mid-Continent region and to some extent on material from Texas as well. Furthermore, the report is founded on studies that extend over many years of field work. Much more detailed and accurate stratigraphic knowledge than has been available at any previous time affords the indispensable starting point for paleontologic investigations that may have practical value in stratigraphy. The volume on Pennsylvanian brachiopods by Dunbar and Condra is hence of much more than local value. It will be sought not only by students of the Pennsylvanian in North America, but will be useful to paleontologists in other continents. In this connection, it should be borne in mind that the Pennsylvanian, or Upper Carboniferous rocks, are probably nowhere in the world better developed than in the Mid-Continent region of North America, as regards well exposed, clearly determinable succession of fossiliferous marine and nonmarine deposits. From the viewpoint of the paleontologist and stratigrapher this section is perhaps the best obtainable standard for the system.

The first feature of the Dunbar and Condra monograph that is likely to attract the attention of a reader acquainted with Pennsylvanian fossils as commonly identified, is the appearance of many familiar brachiopod faces under unfamiliar names. This refers mainly, of course, to the allocation of species in generic groups that have not previously been recognized generally among American Pennsylvanian brachiopods. A few of these new assignments of common species are as follows (the former generic designation being shown in parenthesis): *Chonetina* (*Chonetes*) *flemingi*, *Echinoconchus* (*Pustula*) *semipunctatus*, *Dictyoclostus americanus* (*Productus semireticulatus*), *Cancrinella boonensis* (*Productus pertenuis*), *Juresania* (*Pustula*) *nebrascensis*, *Linoproductus* (*Productus*) *insinuatus*, *Neospirifer* (*Spirifer*) *triplicatus*, and *Punctospirifer* (*Spiriferina*) *kentuckyensis*. Very comprehensive genera, such as *Productus* and *Spirifer*, as formerly defined, have been split up into numerous divisions, the majority of which were first regarded as of subgeneric rank, but in most cases are now given full generic standing. As applied to Pennsylvanian brachiopods, the work of Y. T. Chao in China, Georges Fredericks and B. Licharew in Russia, Ivor Thomas and H. M. Muir-Wood in Great Britain, is especially important. Dunbar and Condra carry further the differentiation of some of the protean genera of late Paleozoic brachiopods, adding to *Derbya* and related shells among the Strophomenidae the new genus *Derbyoides*, to *Chonetes* and its allies which are here placed in the family Chonetidae, the new genera *Lissochonetes* and *Mesolobus*, and to the productids the new genus *Leptalosia*. Other genera introduced by Dunbar and Condra are *Trigonoglossa* belonging to the Lingulidae, and *Wellerella* belonging to the Camarotoechidae. Thus, according to the classification accepted by these authors, the productids are divided into twenty-nine genera, of which eight are represented in the Pennsylvania faunas of the Mid-Continent region; and the chonetids are divided into fourteen genera, of which four occur in the brachiopod faunas here described. Among the renamed common species we therefore find *Lissochonetes geinitzianus*, and *Mesolobus mesolobus*, formerly assigned to *Chonetes*, and *Wellerella osa-*

gensis, previously designated as *Pugnax. Pugnax rockymontana* is recognized as belonging to *Leiorhynchus.* All together 133 brachiopod species and varieties are described by Dunbar and Condra, 56 of them new.

The illustrations, comprising forty-four plates, are pleasing in appearance and appear to be entirely adequate. Line drawings showing structural characters are distributed through the text.

The stratigraphic framework for the paleontologic study of these brachiopods has been presented in some detail in earlier publications of the Nebraska Geological Survey (Bulls. 1 and 3), and with some additions and revision of correlations based on recent work in Kansas, is outlined in the first pages of the brachiopod volume. A large faunal chart shows the stratigraphic distribution of the species described, and this is supplemented by a helpful summary of brachiopod zones in the Pennsylvanian section. Discussion of the use of long-ranging fossil species in detailed stratigraphic correlation and of the relation of species to environment as observed in the course of the Pennsylvanian study is also pertinent.

In the opinion of the reviewer, Doctor Dunbar and Doctor Condra are deserving of special commendation on the completion of this work, first on account of the painstaking taxonomic and morphologic studies that are here reported, and second on account of the very detailed and careful correlation of systematic paleontology with field stratigraphy. It is emphatically true of the Pennsylvanian faunas and floras that paleontologic research of stratigraphic value must involve thorough acquaintance with the occurrence of the fossils in the field. The study of collections of fossils in laboratory or museum, even if the number of specimens is very large, means little if the stratigraphic distribution of the fossils is vaguely or inaccurately known. This is one of the chief sources of difficulty in much of the earlier paleontologic investigation of the Pennsylvanian rocks. Refined stratigraphic knowledge provides basis for the differentiation and subdivision of too comprehensive genera and species, and once the faunal zonation of Pennsylvanian formations of the Mid-Continent region is established, the more narrowly defined biologic groupings of the fossils furnish foundation for more detailed and accurate correlation of geographically distant sections. Much progress in this direction has been made in recent years in study of the fusulinids. Plummer and Scott are far advanced in a comprehensive investigation of Pennsylvanian ammonoids. Work on other fossil groups is actively under way. Multiplication of the number of recognized fossil species in all groups is to be expected, and as the loosely defined "species" of past usage are replaced by more sharply and narrowly drawn species and varieties that have value in precise stratigraphic correlation, paleontologic science will be greatly advanced in practical usefulness. The contribution by Dunbar and Condra on the brachiopods of Nebraska is a notable step in this line of development.

RAYMOND C. MOORE
University of Kansas

SOCIETY RECORDS AND ACTIVITIES

SIXTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

President, C. E. Decker, in the chair
Vice-President, W. S. Adkins
Secretary-Treasurer, Gayle Scott
Editor, Raymond C. Moore

The sixth annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Huckins Hotel at Oklahoma City, Thursday and Friday afternoons, March 24 and 25, 1932. The meeting was in conjunction with the regular annual meeting of the American Association of Petroleum Geologists held at the Biltmore Hotel in the same city, March 24, 25, 26, 1932.

The meeting of the Society was called at two o'clock, March 24, and the presentation of papers was begun at once. The following papers were presented (1-7 inclusive).

The technical session was adjourned at three thirty o'clock and the Society went immediately into business session, items for consideration being taken up in the following order:

(1) Minutes of the previous meeting were read and approved.

(2) The officers, excepting Vice-president and Editor, absent, made their annual reports.

It was moved by M. A. Hanna and seconded by N. L. Thomas that the reports of the officers be accepted and that they be given a vote of appreciation for their services. The motion carried. The President then appointed an auditing committee to go over the Society's books, the following members being designated: M. A. Hanna, *chairman,* F. B. Plummer, N. L. Thomas, M. P. White.

(3) The President then called for reports of standing committees.

(a) Committee to arrange for and promote the preparation of publications of monographs describing and illustrating the fossil faunas of each of the principal geological systems: R. C. Moore, *chairman,* M. A. Hanna, J. B. Reeside, J. A. Cushman, F. B. Plummer, G. D. Hanna. The Chairman being absent, there was no report.

(b) Committee to promote paleontologic research projects: W. S. Adkins (1934), *chairman,* Charles Ryniker (1934), C. C. Church (1934), B. H. Harlton (1933), M. C. Israelsky (1933), R. Roth (1932), S. G. Wissler (1932). The chairman being absent, there was no report.

(c) Committee to arrange for and promote the distribution of cards illustrating and describing American type fossils. This committee was appointed by M. A. Hanna at New Orleans in 1930: F. B. Plummer, *chairman,* M. A. Hanna, G. D. Hanna, J. A. Cushman, R. C. Moore, J. B. Reeside. Mr Plummer made his report showing considerable progress in spite of the economic depression which prevented, up to the present time, the actual printing and distribution of cards.

(4) The question of affiliation with the Paleontological Society for joint publication of the JOURNAL OF PALEONTOLOGY was considered. It was moved by Thomas and seconded by M. A. Hanna that the chair appoint a committee to consider what action should be taken and report back to the business session to be held the following day. The motion carried. The following committee was appointed by the President: M. A. Hanna, *chairman,* F. B. Plummer, N. L. Thomas, Maynard White, Charles Ryniker.

(5) The Council proposed the name of R. T. Hill for honorary membership. It was moved by Stephenson and seconded by Plummer that Dr. Hill be elected an honorary member of the Society. Carried unanimously.

(6) The Secretary reported that nominating ballots which should have been mailed to the membership at least sixty

days prior to the regular meeting (annually), in accordance with By-Laws passed at the San Antonio meeting, had been overlooked. F. B. Plummer then moved, seconded by Hanna, that the By-Laws be set aside for this meeting and that a nominating committee be appointed by the Chair to present candidates at the business meeting on the following day. Carried. The President appointed the following committee: M. A. Hanna, *chairman,* F. B. Plummer, N. L. Thomas, Maynard P. White, Charles Ryniker.

(7) The meeting was then adjourned.

The meeting of the Society reconvened at two o'clock Friday, March 25, and went immediately into business session, items being taken up in the following order:

(8) R. C. Moore, Editor, made his report and it was accepted on motion by Hanna, seconded by Thomas.

(9) The President then called for the report of the auditing committee. Mr. Hanna reported that inasmuch as the Secretary had had a certified public accountant make an audit of the books, the Committee would accept that audit.

(10) The report of the Committee on joint publication with the Paleontological Society was called for. Hanna made the report, discussing at some length the question whether the Society should join in the joint publication project. Hanna had pointed out that the Society must take care not to allow itself to be extinguished. He also pointed out that the JOURNAL had come to occupy a definite place in scientific literature. Hanna moved that the committee on joint publication be continued and be instructed to draft a plan for joint publication and prepare a ballot to be sent to members by mail for their vote. The motion was seconded and carried unanimously.

(11) The nominating committee submitted the following names for officers for the year 1932:

President, G. Dallas Hanna
Vice-President, James Waters
Secretary-Treasurer, Gayle Scott
Editor, Raymond C. Moore

The President then called for nominations from the floor. Mr. Moore rose to say that he was not interested in editing a narrowly conceived journal that will accept for publication only material of an economic nature. The Society should elect someone else as Editor if a strictly "economic" policy is to be pursued. No other candidates were nominated. Moved by Winton, seconded by Hanna, that the ticket be elected by acclamation. Carried unanimously.

Mr. Plummer then extended an invitation to the Society from the Texas Academy of Sciences to have its fall meeting with the Texas Academy.

The business meeting was then adjourned and the meeting went immediately into the technical session, papers 8–25 on the program being offered.

The following papers were presented at the technical sessions of the Society:

1. "Micro-Fossiliferous Upper Cretaceous Section from South Dakota." J. A. Cushman and E. R. Applin, Sharon, Massachusetts, and Fort Worth, Texas.
2. "Regional Distribution of genus *Globotruncana* in Upper Cretaceous Sediments." Hans E. Thalmann, Scheveningen, Holland.
3. "Micro-Fossils from Upper Part of Trinity near Marietta, Oklahoma." H. C. Vanderpool, Norman, Oklahoma.
4. "Foraminifera of the Genera *Flabellammina* and *Frankeina* from Cretaceous of Texas." C. I. Alexander and J. P. Smith, Fort Worth, Texas.
5. "Mesozoic Conodonts." Frank H. Gunnell, Columbia, Missouri.
6. "Inverted Hinge in Left Valve of *Venericardia planicosta* Group." Julia Gardner and Edgar Bowles, Washington, D.C.
7. "Distribution of *Venericardia planicosta* Group North and West of Gulf of Mexico." Julia Gardner and E. Bowles, Washington, D.C.
8. "Unconformities of Weches Formation

in Leon County, Texas." H. B. Stenzel, Austin, Texas.

9. "*Scutella* Bed of East Texas." H. B. Stenzel, Austin, Texas.
10. "New Data on Correlation of Lower Oligocene of South and Central America with that of Southern Mexico." James B. Dorr, Tampico, Mexico.
11. "Recent Ostracodes in Relation to Taxonomy of Fossil Material." W. H. Taylor, Oklahoma City, Oklahoma.
12. "Ostracode Horizon in Lower Permian of Cement Area, Oklahoma." R. W. Harris and Frank Worrel, Norman, Oklahoma.
13. "Micro-fauna of Lower Permian of Kansas." Cecil G. Lalicker, Norman, Oklahoma.
14. "Representatives of Genus *Schwagerina* in Florence Flint of Cowley County, Kansas." Charles Ryniker, Tulsa, Oklahoma.
15. "Contributions to Knowledge of Paleontology of Bend Group." F. B. Plummer, Austin, Texas.
16. "Megascopic Fauna of Cromwell Sandstone." R. V. Hollingsworth, Norman, Oklahoma.
17. "Heavy Minerals in Springer Formation of Ardmore Basin, Oklahoma." E. L. Lucas, Norman, Oklahoma.
18. "Fusulinid Sports." M. P. White, Ardmore, Oklahoma.
19. "New Genus of Fresh-Water Mussel from Catahoula Sandstone of Texas." F. S. MacNeil, Washington, D.C.
20. "Arenaceous Foraminifera of Pre-Pennsylvanian Age of Western Ozark and Arbuckle Regions." R. W. Harris and H. A. Ireland, Norman, Oklahoma.
21. "Concerning Composition of Tests of Early Paleozoic Foraminifera." W. L. Moreman, Fort Worth, Texas.
22. "Classification of the Mississippian System." Raymond C. Moore, Lawrence, Kansas.
23. "Notes on Marine Wilcox." F. W. Rolshausen, Houston, Texas.
24. "Micro-fossils from the Sylvan Shale." S. W. Lowman.
25. "Foraminifera of the Annona Chalk and Pecan Gap Tongue of the Annona." J. A. Cushman, Sharon, Massachusetts.

REPORT OF SECRETARY-TREASURER

March 15, 1932

The membership of the Society of Economic Paleontologists and Mineralogists on March 15, 1932, numbered 241 active members and 83 associate members. Dues were collected July 1 for 1931, and again January 1, 1932, for 1932. During the year, March 15, 1931 to March 15, 1932, the Society elected 33 new active members and 30 new associate members. Applications now pending number 19.

The Secretary has directed his energies toward maintaining and increasing the revenues of the Society through the sale of back numbers of the *Journal of Paleontology,* obtaining new subscriptions, new members, and advertising for the *Journal of Paleontology.* The total paid subscription list of Volume V of the *Journal of Paleontology* amounts to 593. The total paid circulation of the *Journal of Sedimentary Petrology,* Volume I, amounts to 252. At intervals several hundred circular letters illustrating and describing the publications of the Society have been sent out to libraries and laboratories, and to geologists and paleontologists in this country and abroad. A number of letters have also been written to prospective advertisers soliciting business. The total advertising amounts to approximately five pages yielding $340 revenue. This does not include advertisements which will expire and become collectable after March 1, 1932. One page, advertising the publications of the American Association of Petroleum Geologists, is in exchange for an advertisement of publications of the Society in the *Bulletin,* and the one-sixth page advertisement of Max Weg is an exchange for a similar amount of space in *Der Geologie.*

On the Pacific Coast and in the larger cities in Oklahoma, Louisiana, and Texas,

local sections have continued active and interesting monthly meetings have been held. It is hoped that these activities will continue and that additional local sections will be organized.

Numbers 1, 2, and 3 of Volume V of the *Journal of Paleontology* and Number 1 of Volume I of the *Journal of Sedimentary Petrology* were printed by the Mid-West Printing Company at Tulsa, Oklahoma; Number 4 of Volume V of the *Journal of Paleontology* and Number 2 of Volume I of the *Journal of Sedimentary Petrology* were printed by the George Banta Publishing Company at Menasha, Wisconsin.

Altogether Volume V of the *Journal of Paleontology* contains 372 pages and 40 plates in lots of 1200 at a total cost of $4,250.38. Volume I of the *Journal of Sedimentary Petrology* contains 101 pages and was printed in lots of 600 at a cost of $751.76.

The present financial status of the Society is satisfactory as shown by the following statement:

AUDIT

THIS IS TO CERTIFY that I have audited the records of the secretary-treasurer of the Society of Economic Paleontologists and Mineralogists for the period March 15, 1931, to March 15, 1932, and the following represents, in my opinion, a correct statement of receipts and disbursements for that period.

J. W. BALLARD
Certified Public Accountant

STATEMENT OF SAVINGS ACCOUNT

of the

Society of Economic Paleontologists and Mineralogists

for the year March 15, 1931 to March 15, 1932

Balance March 15, 1931		1,500.00
Withdrawals:		
July 30, 1931	$500.00	
October 10, 1931	500.00	1,000.00
		500.00
Deposits:		
January 12, 1932	500.00	
February 1, 1932	500.00	1,000.00
Interest:		
July 1, 1931	23.34	
January 1, 1932	7.84	31.18
Balance March 15, 1932		$1,531.18

Statement of Cash Receipts and Disbursements

Society of the Economic Paleontologists

for the year March 15, 1931 to March 15, 1932

RECEIPTS

*Balance from March 15, 1931	$2,600.35
Donations toward publication, A. A. P. G.	454.00
Subscriptions	2,464.68
Membership Dues	1,551.20
Advertising	340.00
Sedimentary Petrology Subscriptions	1,043.80
Credit from Mid-West Printing Co.	107.69
Savings Account	1,000.00
Interest from Savings	31.18
Redeposited Checks and Exchange	92.35
Total Receipts	$9,685.25

* Savings Account	$1,500.00
* Checking Account	1,100.35
	$2,600.35

DISBURSEMENTS

Secretarial and clerical work	$ 300.00
Postage, express and freight	273.01
Printed forms, stationery, supplies	174.53
Returned checks, cancelled stubs, bank chgs.	115.85
Telephone (long distance and telegraph)	4.19
Expenses incurred in San Antonio Meeting	20.18
Printing of *Journal of Paleontology*	
Volume V, Number 1	784.00
Volume V, Number 2	1,329.68
Volume V, Number 3	1,403.86
Volume V, Number 4	530.97
Printing of *Journal of Sedimentary Petrology*	
Volume I, Number 1	539.05
Volume I, Number 2	139.96
Plates for March *Journal of Paleontology*	330.49
Supplement to Volume IV, Number 4	30.00
To Savings Account	1,000.00
Total Disbursements	$6,976.40
* Balance on hand	$2,708.85

* Savings Account	$1,531.18
* Checking Account	1,177.67
	$2,708.85

ASSETS

Bank Balance			
Savings Account	$1,531.18		
Checking Account	1,177.67		$ 2,708.85
Stock of *Journals:*			
Journal of Paleontology			
Volume II (61 copies)		$ 366.00	
Volume III (90 copies)		540.00	
Volume IV (320 copies)		1,920.00	
Volume V (375 copies)		2,250.00	5,076.00
Journal of Sedimentary Petrology			
Volume I (312 copies)			936.00
Bills Collectible:			
Membership Dues		$ 466.00	
Sales of Journals		648.00	
(55) *Jour. Sed. Petr.* Subscriptions		165.00	
(50) *Jour. Sed. Petr.* Members		100.00	
Advertising		385.00	1,764.00
Journal of Paleontology and *Sedimentary Petrology* for 1932 paid on Volume II			139.96
Total Assets			$10,624.81

The balance of cash on hand as shown in the statement was verified by correspondence with the Fort Worth National Bank of Fort Worth, Texas.

Practically all checks are supported by proper vouchers.

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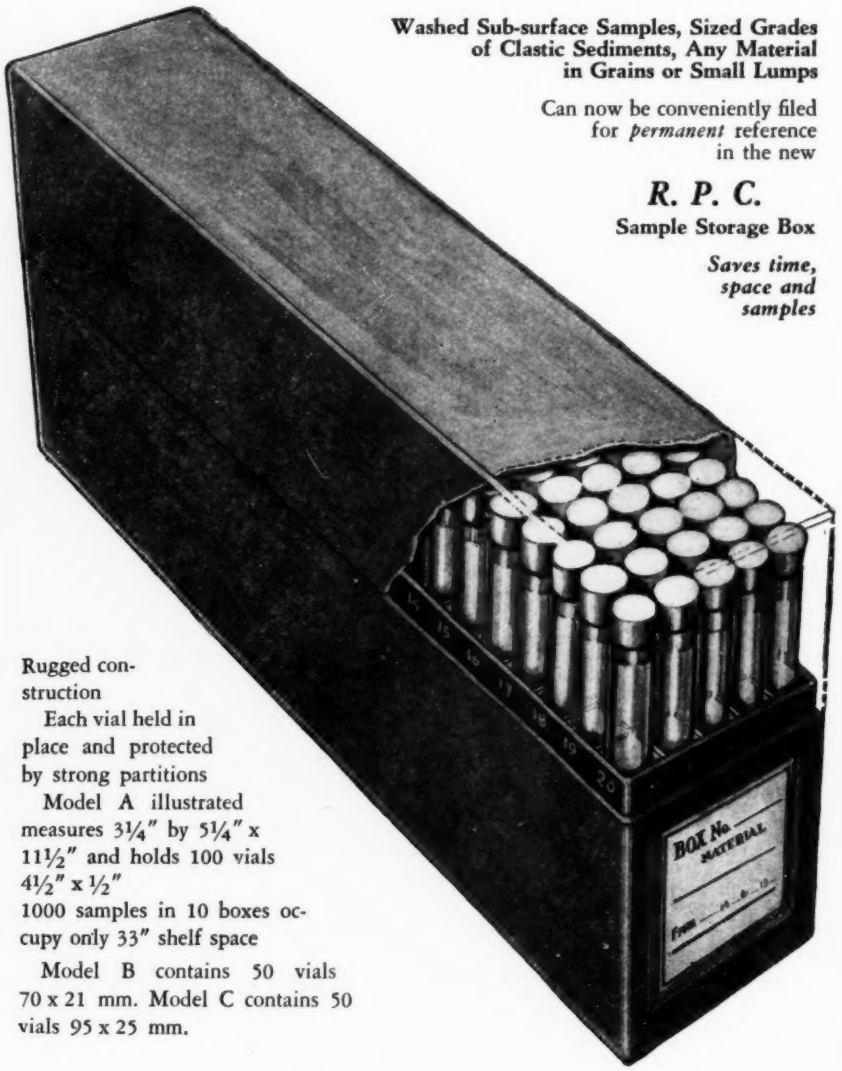

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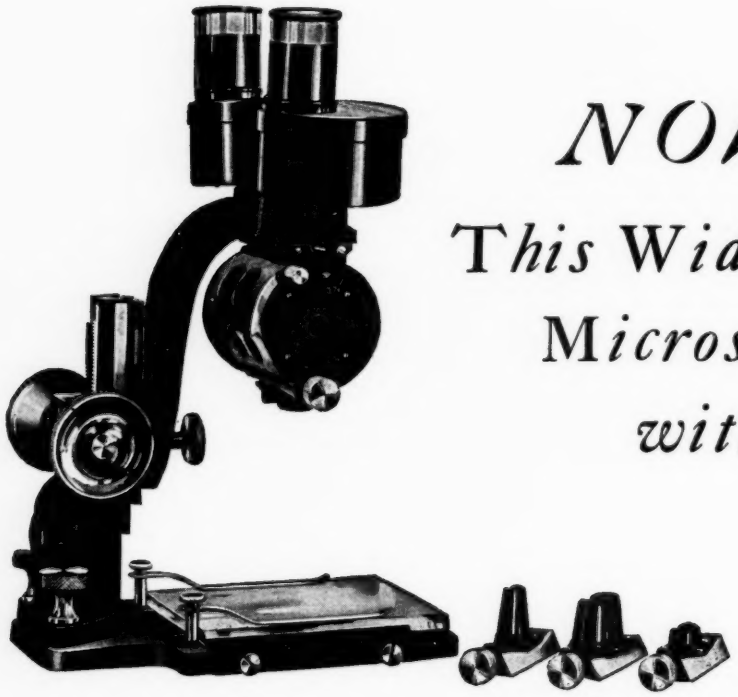

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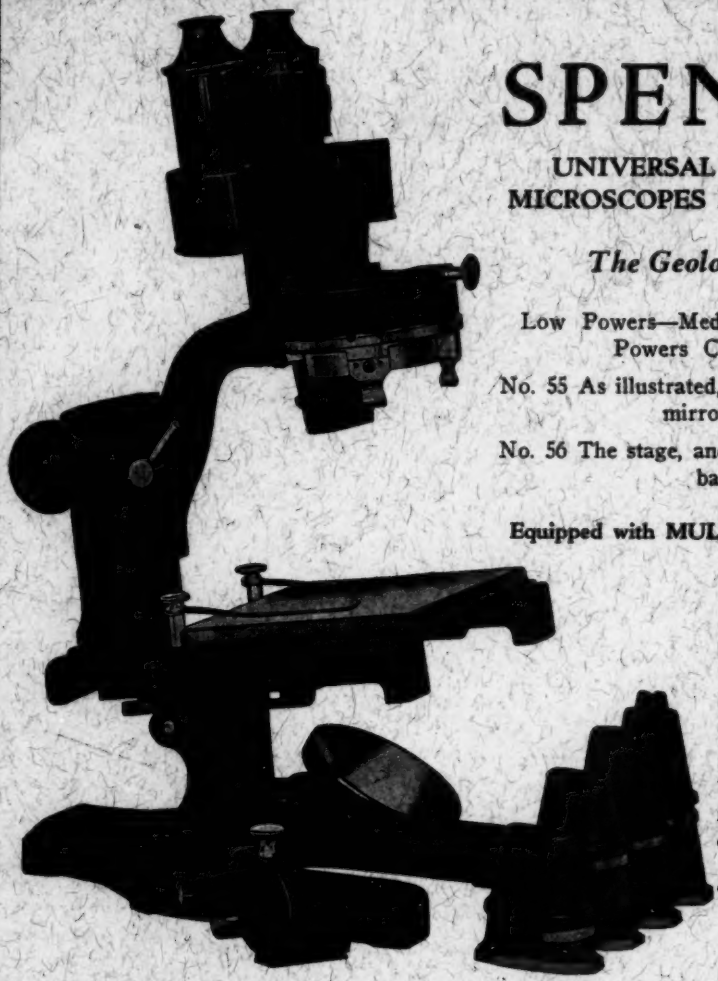

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